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CONFIGURATIONAL LEARNING IN THE GOLDFISH

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INTRODUCTION

The experiment here reported was undertaken for the purpose of studying, under controlled conditions, the learning process in animals fairly well down in the evolutionary scale; and to determine to what extent these animals exhibit 'insightful' activity.

The term insight is used in general in the sense in which Köhler originally used it,[1] and as Helson has also employed it.[2] By it is meant (a) transposition of the general properties from one situation to another, (b) response to a complex, total situation the details of which have been altered without changing their relationships in the total structure, (c) response to parts in the light of a whole, (d) configurational or 'structured' response, (e) reacting to a complex situation in a way that might be called adequate or 'sensible.' Insight seems to describe specific responses in the learning process far better than terms which have to do with alleged learning by chance, or the mechanical selection of responses by means of repetition, recency, satisfyingness and the like.[3] Indeed, it seems clear that our entire conception of animal as well as human learning is undergoing a radical change from a view largely atomistic and mechanistic to one that is organismic and non-mechanistic. The famous laws of association long applied in the psychology of learning do not appear to hold.[4]

[1] Köhler, Wolfgang, *The Mentality of Apes.* (E. Winter, Tr.) London: Kegan, Paul, 1924.

[2] Helson, Harry, "Insight in the White Rat." *Jour. Exper. Psychol.*, Vol. 10, 1927, p. 380.

[3] Cf. Wheeler, R. H., *The Science of Psychology.* New York: Crowell, 1929, 313 ff.

[4] Coghill, G. E., *Anatomy and the Problem of Behavior.* New York: Macmillan, 1929.

Learning is being envisaged not as a synthetic, but an analytical process, a growth and differential process, starting with a total pattern instead of isolated, discrete and elemental performances. Is this newer conception of learning borne out in animals as primitive as the goldfish (*Carassius auratus*)?

Relatively few systematic experiments have been performed on the behavior of fishes, and none, so far as we are aware, has been devoted specifically to the present problem. Studies of transposability have been confined to animals higher in the evolutionary scale.

RELATED STUDIES

In 1886, Vitus Graber[5] attempted an investigation on a number of animals including two species of fish. He offered his fish the choice between two compartments, differently illuminated, and at the end of a given period, counted the number in each compartment. He concluded, because of his method of procedure, that he was testing light preferences and not merely light discrimination.[6]

In 1902, Kinnaman[7] discovered that the monkey perceived relative as well as absolute brightness when pairs of stimuli were used.

In 1911, Casteel[8] observed relative choices in the painted turtle when lines of different width were employed as stimuli. Hints of transposability were also found by Breed.[9]

[5] Graber, Vitus, "Grundlinien zur Erforschung des Helligkeits und Farbensinnes der Tiere." 1886. (Cf. Washburn and Bentley, *Jour. Comp. Neurol. and Psychol.*, 1906, Vol. 16, 113–125.)

[6] In 1895, Kreidl tested hearing in the goldfish and concluded that they do not respond to sounds produced either in the air or in the water, even when they are made abnormally sensitive by strychnine. "Hearing in the Goldfish." (See Parker, G. H., "Hearing and Allied Senses in Fishes." *Bull. U. S. Bureau Fish.*, 1903, Vol. 22, 45–64.)

[7] Kinnaman, A. J., "Mental Life of two *Macacus Rhesus* Monkeys in Captivity." *Amer. Jour. Psychol.*, 1902, Vol. 13, 98–148; 175–218.

[8] Casteel, D. B., "The Discriminative Ability of the Painted Turtle." *Jour. Animal Behav.*, 1911, Vol. 1, 1–28.

[9] Breed, F. S., "Reactions of Chicks to Optical Stimuli." *Jour. Animal Behav.*, 1912, Vol. 2, 280–295.

Washburn and Abbott[10] noticed transposability in the reactions of the rabbit to pairs of greys. In the next year, 1913, Bingham[11] discovered that chicks made relative choices when circles of different sizes were used. In the same year, Coburn[12] observed much the same type of response in the crow. Also Johnson,[13] from 1914 to 1916, working with the chick and the monkey verified the fact of transposability, but ascertained certain conditions under which the subjects seemed to prefer absolute rather than relative degrees of stimulation.

Maze learning in the goldfish was investigated by Churchill[14] in 1916. Although the goldfish lacks a pallium, it was capable of forming a definite habit of a moderate degree of complexity and of retaining it for a considerable period (13 days). Churchill concluded that, "the senses of sight and touch were instrumental in the initial steps of the habit formation, but later were superseded to a great extent by kinaesthesia." The experiment, antedating our own on fish as subjects, that most closely approaches the present problem, was a study of the mudminnow by Schaller[15] in 1926. Schaller found by presenting edible and nonedible foods on needles surmounted simultaneously by colors and geometrical forms, that the fish seemed to distinguish readily either the color or the form cues. When his subjects had learned to discriminate two cues differing both in color and form he transferred them to new pairs of cues with color and form relationships reversed. If the two original cues differed predominantly in

[10] Washburn, M. F., and Abbott, E., "Experiments on the Brightness Value of Red for the Light Adapted Eye of the Rabbit." *Jour. Animal Behav.*, 1912, Vol. 2, 145–180.

[11] Bingham, H. C., "Size and Form Perception in *Gallus Domesticus*." *Jour. Animal Behav.*, 1913, Vol. 3, 65–113.

[12] Coburn, C. A., "The Behavior of the Crow, *Corvus Americanus Aud.*" *Jour. Animal Behav.*, Vol. 4, 185–201.

[13] Johnson, H. N., "Visual Pattern Discrimination in the Vertebrates." *Jour. Animal Behav.*, 1914, Vol. 4, 319–339; 340–361. 1916, Vol. 6, 169–188.

[14] Churchill, E. P., "The Learning of a Maze by Goldfish." *Jour. Anim. Behav.*, 1916, Vol. 6, 247–255.

[15] Schaller, A., "Sinnesphysiologische und psychologische Untersuchungen an Wasserkafern und Fischen." *Zsch. f. verg. Physiol.*, 1926, Vol. 4, 370–464. (See Tolman, E. C., *Psychol. Bull.*, January, 1928.)

color the fish responded to color in the second experiment. If, however, the original cues differed predominantly in form the fish responded to form in the transfer experiment. These results, as well as previous studies on fish, testify to the rather sharp acuity of vision in these animals.[16]

Gotz, in 1926,[17] working with hens under carefully controlled conditions, found that when they had been trained to choose the larger of two grains of corn and both grains were approximately the same distance at the moment of choice, they would still select the actually larger grain when it was a sufficiently greater distance from the 'choice point' to cast a retinal image only one-thirtieth of that cast by the smaller grain. Even when variations of perspective foreshortening were introduced, caused by turning the grain at different angles relative to the vision of the approaching bird, this *Sehgrossenkonstanz* was maintained.

As a result of work done on the white rat in 1926, Higginson[18] concluded that the significance of one part or object within the stimulus-pattern rests upon its induction into a total situation, resulting in a partial or total submersion of the individual characteristics of the object into a unified whole. A unifying process evidently goes on, according to Higginson, in which the recognized relation of a member to the whole does not arise through a period of trial and error, but quite suddenly. He says, further, that the goal is always functioning as an integral part of the total *Gestalt*, governing the animal's performance by unifying the individual members into a whole.

[16] Hineline, G. M. W., in 1927, tested color discrimination in the mudminnow, under rigidly controlled conditions with infra-red and ultra-violet eliminated by filters. The fish seemingly distinguished red and green, yellow and blue, but not blue and green. "Color Vision in the Mudminnow." *Jour. Exper. Zool.*, 1927, Vol. 47, 85–94.

In 1923, Berkamp reported in an investigation of fishes that these animals responded in a relational way to the dimensions of stimuli presented in pairs.

[17] Gotz, W. "Vergleichende Untersuchungen zur Psychologie des optischen Wahrnehmungsvorgange I. Experimentelle Untersuchungen zum Problem der Sehgrossenkonstanz beim Haushuhn." *Zsch. f. Psychol.*, 1926, Vol. 99, 247–260. (See Tolman, E. C., *Psychol. Bull.*, January, 1928.)

[18] Higginson, G. D., "Visual Perception in the White Rat." *Jour. Exper. Psychol.*, 1926, Vol. 9, 337–347.

Kroh and Scholl[19] investigated, in 1926, the relative dominance of form and color perception in hens, with the result that color was found to be dominant. Révész has suggested that this type of response should be called *teilinhaltliche Beachtung.*

Révész,[20] in 1924, while studying optical illusions in the hen, trained his animals to choose the smaller of two circles. Without any introductory training the animals then chose the smaller of various other geometrical forms, presented in pairs. Segments of circles of different sizes were then presented in various awkward positions with the result that the animals still chose the smaller. Two congruent segments in the form of the Jastrow illusion were next given the hen, with the result that the animal walked across the 'subjectively larger' segment, without touching the grain, and pecked from the 'subjectively smaller' segment. In a final test three segments were presented, two identical and one smaller; the 'objectively smaller' was placed nearest and the 'subjectively smaller' was farthest away. The hens first pecked from the 'objectively smaller' segment and then passed on to the 'subjectively smaller' segment, leaving the middle segment untouched. Another test demonstrated the fact that hens are also subject to the optical illusion which involves the underestimation of horizontal lines in comparison with vertical lines.

In 1927, Helson[21] experimented with the white rat in order, by means of the following criteria, to determine from its behavior evidence for what Köhler designated as 'insight.' Response to a part in the light of a whole; modifiability of behavior to meet a new situation in a manner that may be called sensible; and transposition of the general properties from one situation to another—precisely the nature of the present problem. He concluded that

[19] Kroh, O., and Scholl, R., "Vergleichende Untersuchungen zur Psychologie der optischen Wahrnehmungsvorgange II. Über die teilinhaltliche Beachtung von Form und Farbe beim Haushuhn." *Zsch. f. Psychol.*, 1926, Vol. 100, 260–273. (See Tolman, op. cit.)

[20] Révész, G., "Experiments on Animal Space Perception." *Brit. Jour. of Psychol.*, (Gen. Sect.) Vol. 14, Pt. 4, 1924, 386–414.

[21] Helson, Harry, "Insight in the White Rat." *Jour. Exper. Psychol.*, 1927, Vol. 10, 378–397.

this animal does possess insight, and that when the conditions of chance are maintained no learning will follow. This insight can not be explained away, according to Helson, by any theory that begins with meaningless unit activities joined together without significance.

In 1927, working with the hen in order to ascertain the after-effects of practice that might appear in situations different from those of the original learning, Kroh[22] took subjects that had been trained under certain conditions to choose the larger of two grains of corn. Similar stimuli were then given them under various new conditions. The result was that the animal chose the larger grain in the following situations: Pairs of large and small grains in different corners of the room; three grains of different sizes, the two larger being eaten; two large and two small grains, the smaller not taken; corn replaced by grains of wheat and bread, resulting in the devouring of the larger object regardless of form and color. Geometrical figures were used in some instances with the result that the hens were able to distinguish triangles from squares, circles and certain other forms. In spite of the fact that the hens were trained with equilateral triangles, they treated all triangles in new situations as triangles, even equilateral ones turned upside down. Some of the hens retained this learning after four months.

In the same year, Takei[23] taught hens to choose between grey and black, grey and white, the larger of two circles, and between rectangles and other kinds of parallelograms. When a transposition from black and grey to grey and white was tried, Köhler's results were not confirmed, but when the transposition was made with circles as stimuli, relative choices appeared. The results on the whole were such that the author adopted the concept of insight rather than the conventional notion of an 'associative trial and error mechanism.'

[22] Kroh, O., "Weitere Beiträge zur Psychologie des Haushuhns." *Zsch. f. Psychol.*, 1927, Vol. 103, 203–227. (See *Psychol. Abst.*, January, 1928.)

[23] Takei, K., "On Visual Discrimination and its Learning with Chickens." *Jap. Jour. Psychol.*, 1927, Vol. 2, 32–87. (Cf. *Psychol. Abst.*, Vol. 2, No. 9, 1928.)

GENERAL EXPERIMENTAL PROCEDURE

The data which comprise the subject matter of this report are divided into six groups, according to the time of the experiment and the method employed. In all, 42 goldfish were used, that made a total of 6,203 choices. As the procedure, method and apparatus differed slightly with each group, they will be described separately in the order in which they were performed.

The animals were fed on commercial food throughout the experiment. However, they were not fed outside the apparatus, or at any time other than during the actual experimentation, except on days when no experiments were conducted. In the first five groups the fish were kept in large bowls, three or four fish in a bowl. Individual fish were distinguished by characteristic markings. In the last group each fish was kept in a separate bowl labelled with the number of the fish.

Group I

Group I contained nine fish (numbers 1 to 9), trained for 18 days. This group was divided into two subgroups, A and B, because two different procedures were adopted. Subgroup A consisted of fish numbers 1 to 4. Two lighted compartments formed an angle of 90 degrees (Figure A1) in an aquarium which was filled with water to a depth of about four inches. The compartments were placed close to the side of the glass so that there was a triangular space in front of them from which the fish could escape only by entering one of the compartment doors. The lights in the compartments were of two intensities, designated as bright and dim, the bright, a 40-watt Mazda lamp, and the dim, a similar lamp diminished in intensity to a relatively faint light. Each lamp was connected with a rheostat so that the spatial relationship of the bright and dim intensities could be changed from left to right or *vice versa*. Food of a standard commercial variety was placed in both compartments, but the fish were only allowed to feed in the dim compartment. A shock, consisting of a vigorous scare with a stick, was administered when the subjects entered the 'bright' compartment. In order

not to give the fish any cues, precautions were taken here, as in all experiments, by not shocking them until they had completely entered a wrong compartment. The food-compartment (dim) was placed in one position for ten minutes and at the end of that time was shifted to the other position, along with a reversal of the light intensities. The experiment extended for twenty min-

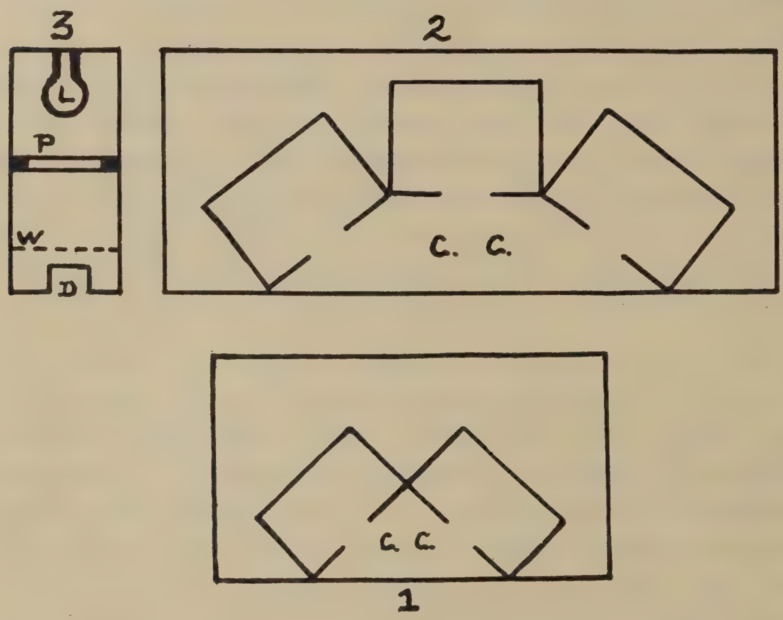


FIG. A

1. Apparatus used in Group 1.
2. Apparatus used in Groups 2–6.
3. Side view of single compartment.

L, light; P, ground glass partition; W, water-line; D, door into compartment; C, C, choice compartment from which fish made their choices.

utes for each fish each day. During this period of twenty minutes the fish were permitted to make as many runs as they chose.

After seven days the fish were transposed to a dim and dark combination of stimuli, the dim of the same brightness as before; but the dark compartment contained *no light*. The following day the periods were reduced to five minutes and two sets or combina-

tions of lights were used, that is, in the first ten minutes a bright and a dim light appeared, alternating in position at the end of five minutes. During the second ten a dim and dark combination was used with positions alternating at the end of five minutes.

On the twelfth day a shift was made in the position of the bright and dim lights after each trial up to five trials, or in case the fish had not made five trials, to a period of ten minutes. At the end of this time a test-trial was given, consisting of a dim and a dark light, with the wrong compartment in the position of the last correct one. Tests were given on the fourteenth day with the food-compartment first on one side and then on the other. A transposition was made on the fifteenth day consisting of a relative increase in the intensities of both lights to the degrees bright and medium. The procedure was the same as before, including the two tests with dim and dark compartments.

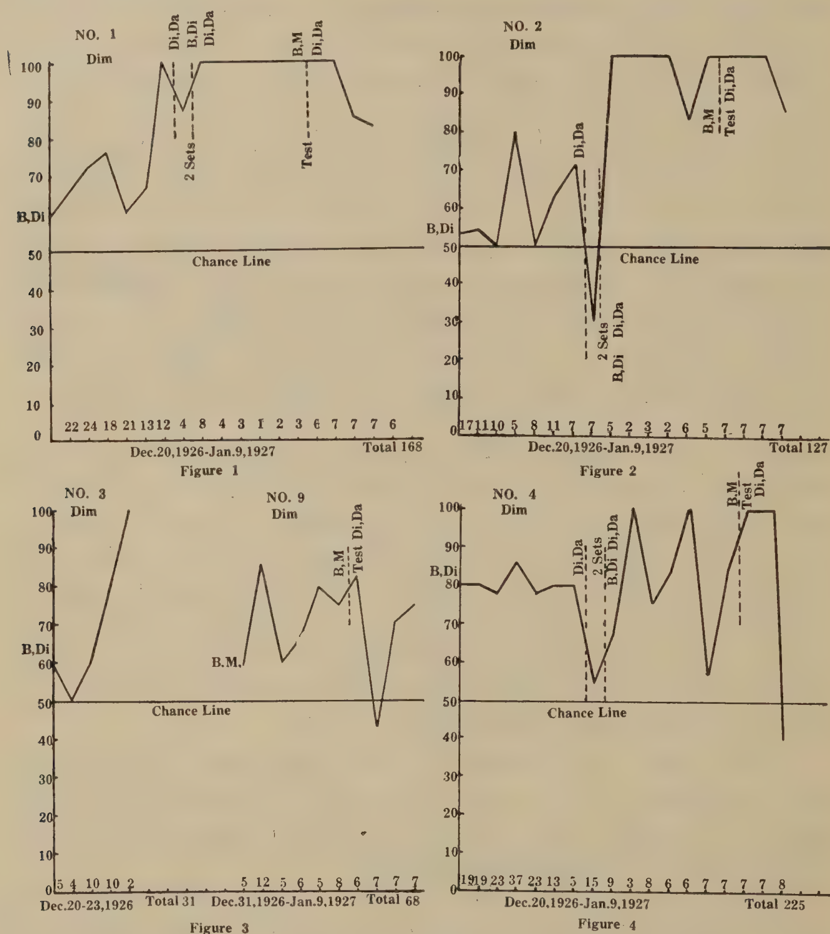
Subgroup B was composed of fish numbers 5 to 9. The apparatus was the same, except that the two intensities of light were bright and medium, the bright as before a 40-watt lamp and the medium produced by increasing the intensity of the dim light to one-half the distance between it and the bright light. The food-compartment, or medium-lighted compartment, appeared on one side for the first five minutes and then on the other side for five minutes, until four positions had been used, taking twenty minutes. At the end of this period a test-trial was given with a dim and dark combination of lights.

On the third day positions of the lights were reversed after each response up to five responses, or to ten minutes, and at the end of this period, two test-situations were presented, with dim and dark lights alternated in position.

Results from Group I. Fish number 1 began with 59 per cent correct choices, or nine points above chance. (See Figure 1.)[24] The drop in the curve after the fourth day was followed by a

[24] Units along the abscissae in all figures indicate numbers of days practice. The numbers indicate the number of trials on any given day. Units along the ordinates indicate the per cents of correct choices. Legend: B, bright; BB, double-bright; Da, dark; Di, dim; M, medium. For example, No. 1, dim, means fish number 1, trained to choose the dimmer light.

rapid rate of learning during the two succeeding days that ended at 100 per cent. It seems improbable that the steep ascent of the curve can be accredited to chance factors; rather, it indicates the



FIGS. 1–4

development of 'insight.' The drop after the seventh day was evidently an immediate result of the transposition that took place then, but the score was raised to 100 per cent the following day. The animal's insight into the problem was apparently

sufficient to permit the same degree of accuracy after the transposition had been made on the fifteenth day. The descent of the curve at the end of the experiment may have been caused by excessive repetition of the task, by inadequate spacing of trials, or by some other factor not under control.[25]

The following facts seem to justify the use of the term insight in connection with the behavior of the goldfish under the present experimental conditions: (1) Steep ascents in the learning curves are obviously too frequent to be explained as chance occurrences; (2) twenty-one, or 50 per cent, of the curves show long, steep ascents and of this number, 80 per cent reveal little or no subsequent loss in the learning; (3) where there are sudden losses there are generally correspondingly sudden recoveries, a fact which may mean only that insight is at times as unstable in animals as we find it in children and adults. (For example, a person may be able on one day to solve a certain mathematical problem or a mechanical puzzle, but on a subsequent day he may fail.)

Fish number 2 (Figure 2) made a less regular performance than number 1, but its entire curve is above the chance line, except for the drop after the seventh day, when the transposition was made. The steep ascent of 70 points between the eighth and ninth days may be interpreted to illustrate again the sudden development of insight. The animal undoubtedly perceived the goal, at this point, as a member of the configuration presented it. The two drops in the curve, after 100 per cent had been reached, may again be the result of faulty spacing or of excessive use of repetition. It should be noted in this connection that *the transposition on the fourteenth day failed to produce any change in the animal's behavior.*

The entire curve of the performance of number 3 (Figure 3) was above 50 per cent. The ascent of the curve is steep and regular to perfect performance which was attained in five days.

[25] Cf. Snoddy, G. S., "An Experimental Analysis of a Case of Trial and Error Learning in the Human Subject," *Psychol. Mon.*, Vol. 20, No. 124, for discussion of irradiation and the effect of inadequate distribution of work and rest periods in learning.

Unfortunately this subject died on the sixth day before a transposition was made; nevertheless, the curve seems to indicate again the rapid development of insight, and is included here because the rapidity of the learning was so striking.

The performance of number 4 (Figure 4), although above the chance line except on the last day, was very irregular. It reveals only a relatively slight amount of learning because the fish started with 80 per cent correct choices. Its behavior was affected by the transposition in one instance and not in another; however, the steep ascents in the curve all indicate that mere chance factors are insufficient to explain the performance, and that a degree of insightful activity is taking place. The decline on the last day was probably caused by a pathological condition of the fish, for the animal died shortly after the experiment was completed.

The graph of number 5's performance (Figure 5) commenced 38 points above chance and went to 100 per cent on the second day. A decline followed which was regained in three days when 100 per cent accuracy was attained. Although the transposition on the seventh day failed to result in an increase in errors, a loss occurred the following day, but was recovered quickly. This curve, like several of the others, strongly points to the difficulty of controlling the animal's behavior. Number 6 (Figure 5) gave a curve roughly comparable to that of number 5, but showed more learning.

The curves of numbers 7 and 8 (Figure 6) are very similar in nature and both average well above the chance line. They commence at 100 per cent then lose and gain that level several times. Number 7 makes large drops but each time regains perfection suddenly, finally ending with 100 per cent. The transposition after the sixth day caused a marked loss from which the animal recovered on the following day—a level maintained to the end of the experiment.

The curve of number 9 (Figure 3) is relatively low, yet most of the scores were above 50 per cent. This fish was not disturbed on the day of the transposition, but on the following day made a very poor performance never to return to the original degree of accuracy.

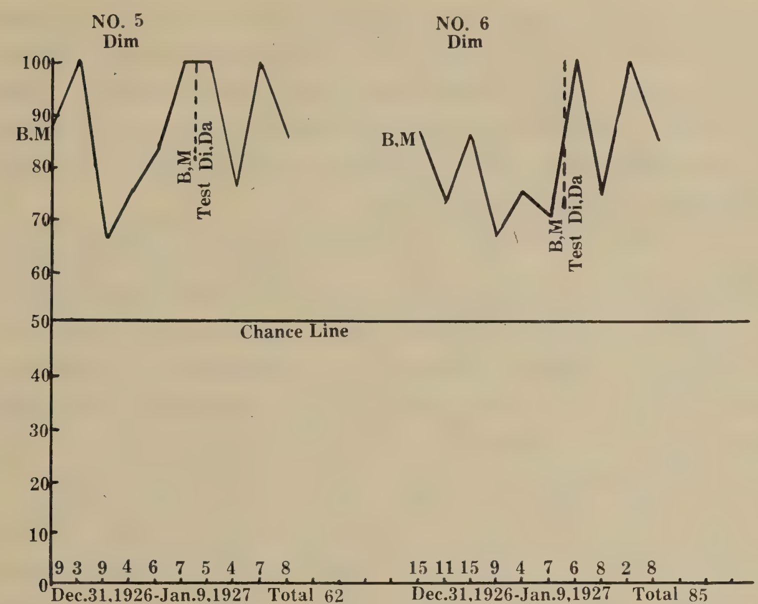


Figure 5

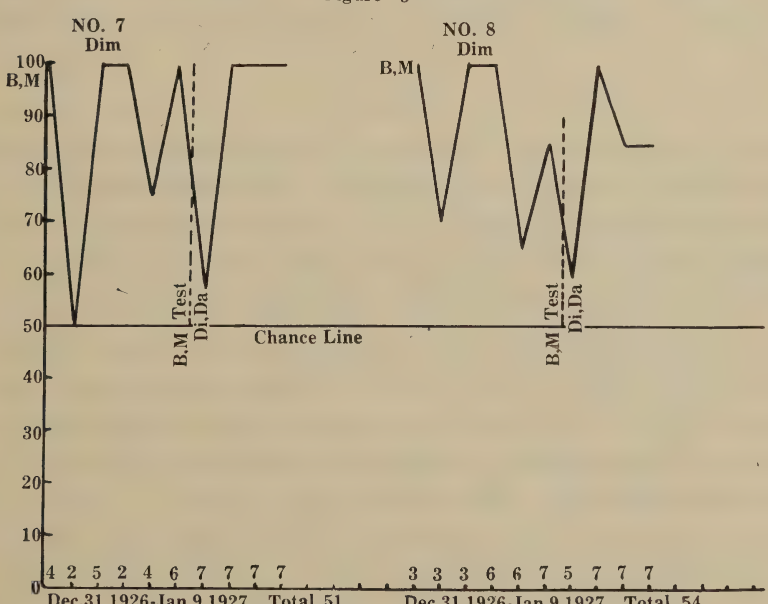


Figure 6

FIGS. 5–6

It is obvious that the experimental procedure for subgroup 1 B, (numbers 5 to 9) was inadequate to condition effective learning. Fewer runs were made, which increased the chances of perfect performance. About the only conclusion that can be drawn from these curves is that transposition did not alter the type of performance exhibited by the fish.

The fact that these subjects were inclined to choose the light of medium intensity in preference to the brighter light, and therefore showed almost no learning, points to a very interesting problem; namely, whether or not there is a tendency for the fish to select lights of medium intensity, or 'middleness,' rather than lights of high or low intensities. That this trend is very significant cannot be maintained too confidently in face of the relatively small number of trials per day made by each fish; but it will appear later that this trend is again evident when a light of relatively medium intensity is presented simultaneously with a lighter and a darker stimulus. More striking, however, is the same trend when the intensities of the lights are constantly changing (Group 6). This problem will be discussed in detail, later.

Group II

Group II contained five fish. The apparatus consisted of three boxes arranged in a semicircle which was closed by the side of the aquarium (Figure A 2). At the beginning, two of the compartments were open and one was closed, the open ones lighted by dim and dark intensities of light, the same as in Group I. An alternation was arranged after each response so that the open compartments, with light-intensities dim and dark, and the closed compartment, were never in the same position two trials in succession. Food was placed in all the compartments; a stick, out of the range of the vision of the fish, was placed in the shock compartment. The animals were kept in the apparatus ten minutes where they were allowed to make a maximum number of trials, but were permitted to eat only in the food-compartment.

Fish numbers 10, 11 and 12, constituting subgroup A of this group, were trained to go to the dark compartment. After the

eighth day they were transposed to a situation with three lights; namely, bright, dim and dark, the bright a 40-watt lamp, and the dim and dark the same as before. On the twelfth day a shift was made back to two lights, bright and dim. Three lights were again presented after the thirteenth day, consisting of bright, medium and dim intensities. After the fifteenth day the entire series was increased in intensity by substituting a 60-watt lamp for the 40-watt stimulus.

Subgroup B included fish numbers 13 and 14, trained to select the brighter light (dim). After the fourth day, number 13 was transposed to three lights, namely, bright (40-w), dim and dark. Number 14 was kept on the original combination until the eighth day, when it was presented with three lights: Bright, dim and dark. On the eleventh day numbers 13 and 14 were put back on a two-light combination, consisting of a bright and dim light, with the third compartment closed. After the thirteenth day, both fish were again given a three-light combination, namely, bright, medium and dim. The entire series was increased in intensity on the fifteenth day by the introduction of a 60-watt lamp in place of the bright light (40-w).

Results from Group II. The curve of number 11 (Figure 7) shows a gradual ascent toward 100 per cent, with a performance of 88 per cent at the outset. In three out of the four transpositions a slight loss followed, but this was quickly regained in each case on the following day. The curve gives us further substantiation of insightful activity; mere chance factors could hardly operate through a series of transpositions of this sort. *Moreover, the curve shows a gradual rise through the several transpositions.*

Number 12's performance (Figure 8) is less regular but it shows an ascent to 100 per cent on the eleventh day, this marked by steep jumps in several instances. The latter part shows a slight decline in the number of correct responses, broken at the end with the beginning of an ascent. Improvement took place after the first and fourth transpositions.

Number 13 (Figure 9) shows a decided loss after the initial problem had been learned; nevertheless, the general trend of the curve is upward from then on, in spite of transpositions.

The responses of number 14 (Figure 10) are all above the chance line. No definite learning was exhibited when the performance as a whole is considered. Evidently what has been designated as insight did not develop appreciably in this case.

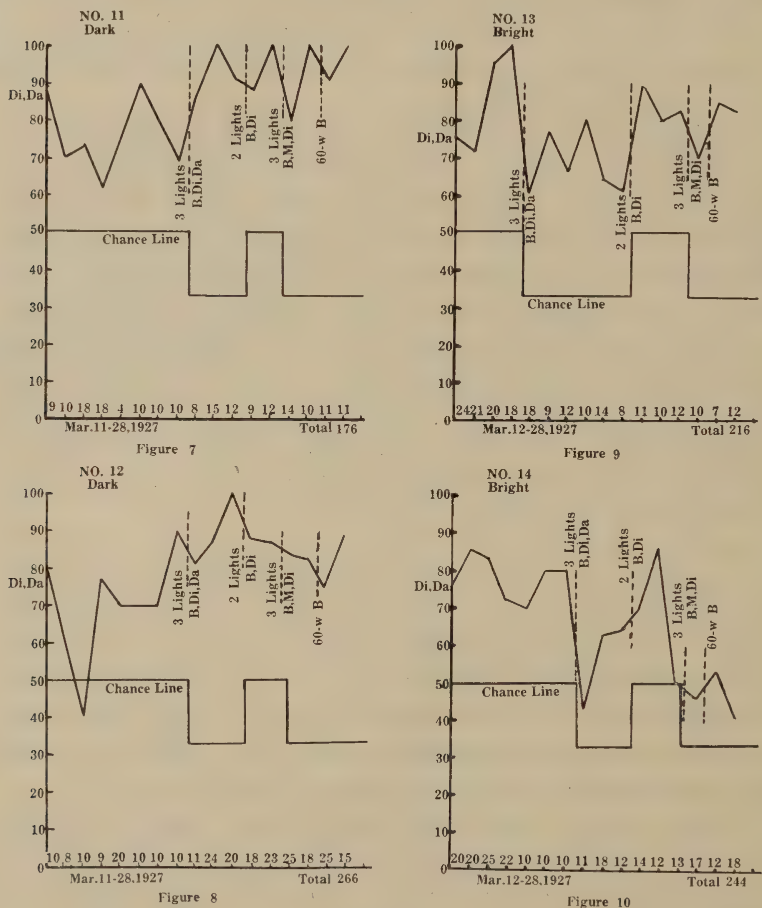


Figure 7 Figure 9 Figure 8 Figure 10

FIGS. 7–10

The question naturally arises in this connection, Are we dealing with a relatively 'stupid' subject?

It is interesting to note that all the subjects of this group commenced with a relatively high average score on the first day.

One reason for this, obviously, is the large number of trials made; another is the possibility that the step from dim to dark was relatively easy for the animal to perceive. Later, we shall see that, under the conditions of our experiment, steps toward the dimmer end of the intensity-scale seemed much easier to learn than steps toward the brighter end of the intensity-scale. The two fish chosen to select their food from the brighter compartment were much more active than the two that were directed to the dark compartment, but on the whole showed less learning. They were more disturbed by the transposition to a combination of bright, dim and dark lights, no doubt caused by the fact that they were confronted with a double step, namely, from bright to dim, while the other two fish faced the simpler problem of perceiving the same interval, dim to dark, in a larger whole.

Group III

Five fish constituted Group III, which was also divided into two subgroups, A and B. The apparatus consisted of three compartments arranged in a semicircle, as in Group II, two of which were lighted with bright and medium lights, the third compartment kept closed. The relative position of each light-intensity, and the closed compartment, was changed after each response. A 60-watt lamp was used in the bright compartment and the medium intensity was produced by decreasing a similar lamp to approximately one-half by means of a rheostat. The fish were kept in the apparatus for ten minutes, and allowed to make a maximum number of choices in that time. Food, placed in all compartments, was used as a goal, and a shock in the wrong compartment consisted of vigorously scaring the animal with a small stick.

In subgroup A, made up of numbers 15 and 16, the fish were to choose the lesser intensity of light (medium), to secure food, and to avoid the greater intensity of light as the shock compartment. After the sixth day these fish were transposed to a situation with medium and dim lights, the third compartment still closed. At the conclusion of the tenth day another transposition took place, this time to a situation in which a varying combination

of five intensities appeared. Only two lights were presented at the same time, but no one succeeded itself or was in the same position twice in one day. These relative intensities were double-bright, bright, medium, dim and dark, the double-bright produced by an introduction of 100-watt lamps in place of the 60-watt lamps. On the fifteenth day these animals were presented with three lights, using the same varying combinations of intensity and position.

Fish numbers 17, 18 and 19 formed subgroup B. These fish were trained to choose the greater intensity (bright, 60-watt) and to avoid the lesser intensity. After the seventeenth day a transposition was instituted to a situation containing five intensities of light, namely, double-bright, bright, medium, dim and dark, made possible by the substitution of 100-watt lamps. Only two lights appeared at the same time; the same light did not appear on two successive trials, or in the same position twice in one day. On the twentieth day three lights were presented, varied in intensities and positions as before.

Results from Group III. Number 15 (Figure 11), chosen to go to the medium light, started at 100 per cent and fluctuated around that point until the last part of the experiment when a gradual decline took place. The fish then died, which leads us to suspect that the loss in learning was caused by a diseased condition of the animal. The question at once arises, Why was this subject's score so high at the outset? Was this fish, and not others, negatively phototropic? If we compare its curve with that of number 17 we discover a possible clue. Number 17 commenced with a score far below chance because it erroneously chose the medium light. One might say that the fish were inclined to avoid bright lights were it not for the fact that when three lights are used (Group 6) there is practically as marked an avoidance of the dark. Accordingly, it would seem that lights of medium intensity are perceived in some fashion with reference to extremes of intensity, both above and below, and are selected in preference to these extremes. In other words, 'middleness' in intensity seems to be preferred—it is the goal which most readily functions in resolving the tension under which the animal is behaving.

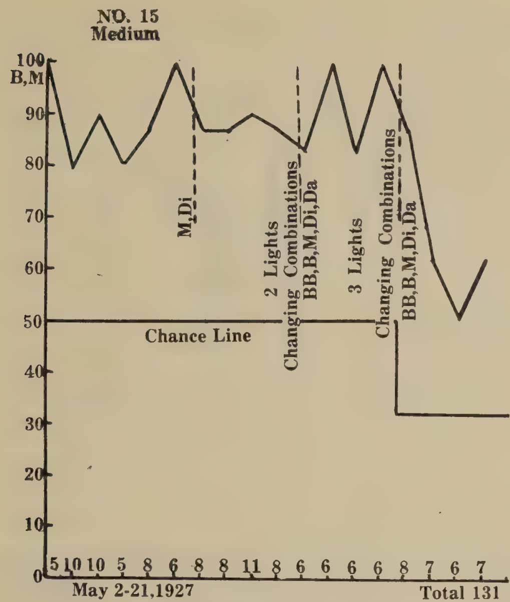


Figure 11

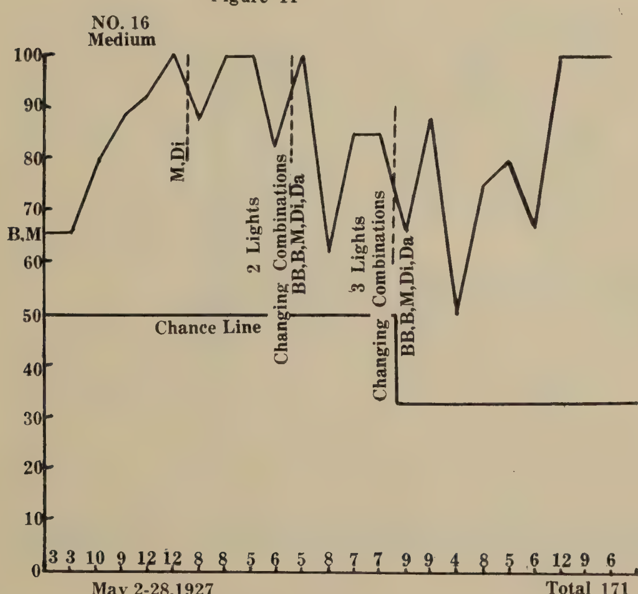


Figure 12

FIGS. 11–12

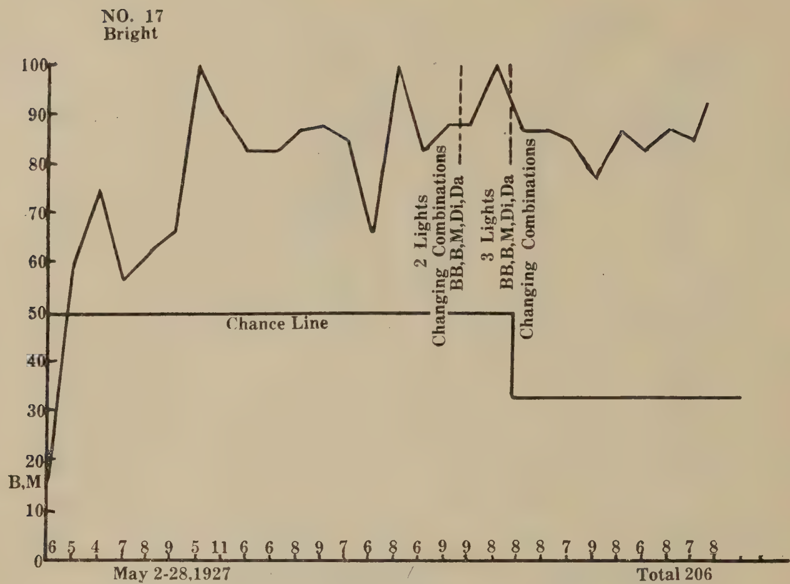


Figure 13

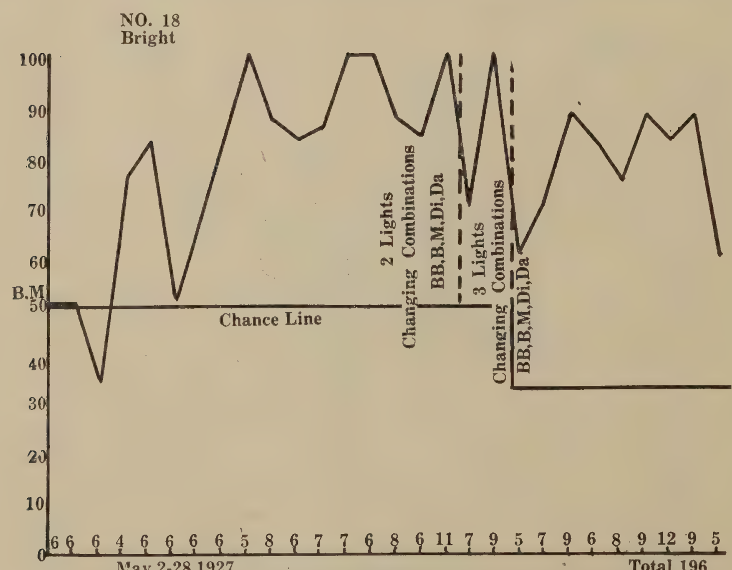


Figure 14

FIGS. 13–14

Number 16's curve (Figure 12) can be divided into two parts by virtue of the fact that there were two distinct ascents to 100 per cent. The first ascent was quite regular, showing apparently that the animal gradually gained insight into the problem. After the striking loss on the twelfth day the ascent is more rugged, characterized by steep ascents and declines, representing, we believe, a condition that may be called the 'unstable insight' mentioned above. The final ascent of 36 points (really 50) can hardly be attributed to any other factor than to insightful activity.

The extended ascents in the curve of number 17 (Figure 13) were a distinctive feature of its performance; even the descents were regained by steep climbs. Outside of the first day, all of the curve was considerably above chance. The transpositions were marked by a pause in the ascent, or a slight loss, which was regained until the curve ended at 100 per cent.

The curve of number 18 (Figure 14) was very irregular; it was marked by steep ascents and rapid descents, but finally gained 100 per cent on the eighth day and again on the twelfth, thirteenth and eighteenth, before the transposition took place. The first transposition resulted in a loss which was regained the following day; but the second transposition, a more difficult one, resulted in a lowering of the curve. The decline at the end, although not marked, indicates perhaps that insight into the problem was unstable or that the length of the experiment was affecting the animal's behavior.

Number 19 (Figure 15) showed from its graph, certain evidences of insightful activity in the steep ascents of the curve. The curve started at 100 per cent, obviously because of chance factors, but regardless of the extreme loss, the curve ascended steadily to 100 per cent on the eighth day. The loss after the eighth day was followed by a gradual ascent to 100 per cent again, at which point the subject died, before a transposition was made. All the curves of this group show that transpositions to three lights reduced the accuracy of performance to a slight extent.

Group IV

In Group IV, consisting of fish numbers 20, 21 and 22, the apparatus consisted of three lighted compartments, arranged as before, with the intensities, bright (60-watt), medium and dim. The lights were changed in position after each response. The animals were trained to choose the medium intensity of light regardless of position. Sticks were placed in the bright and dim compartments to use as a shock in case of a wrong response. (These sticks were not visible from the 'choice-compartment.') Each fish was allowed to make the maximum number of responses in the time allotted, namely, ten minutes. As in all the experiments, food was used as the goal, placed in each compartment in order to avoid the possibility of a response on the basis of olfactory cues. After the twelfth day a transposition was made to a problem with five varying intensities of light, with the three changing positions after each response. The lights were double-bright (100-watt), bright, medium, dim and dark.

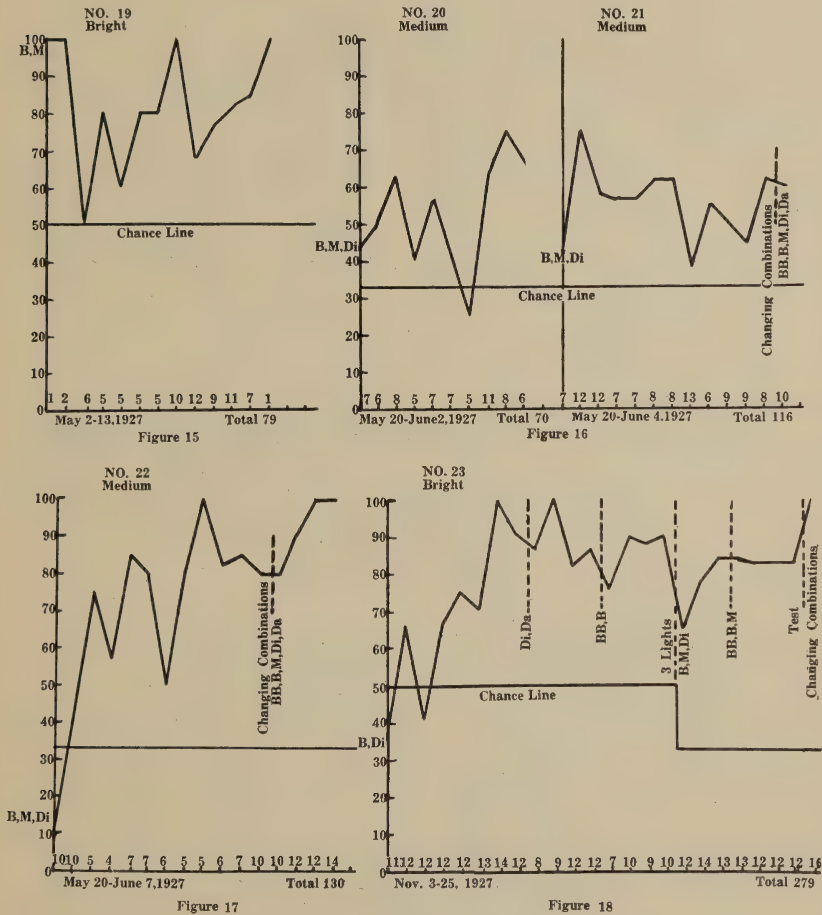
Results from Group IV. The curves for numbers 20 and 21 (Figure 16), although not close to 100 per cent at any time, were mostly above the chance line ($33\frac{1}{3}$ per cent). The lack of perfection may have been caused by the condition of the animals, both of which died before the end of the experiment. Number 22's curve (Figure 17) is remarkable for the steep ascents to 100 per cent in the first part of the experiment. *This, along with other steep ascents previously mentioned, seems rather conclusive evidence of the development of insight into the problem presented. The transposition failed to have any inhibiting effect on the learning.*

Group V

This group contained five fish, divided into subgroups A and B. The apparatus consisted of the three boxes arranged as before with food in each compartment, a stick being used as a means of shocking the animals when wrong responses were made.

Subgroup A included fish numbers 23 and 24, trained to choose the greater intensity of two lights, bright (60-watt) and dim, regardless of position, with the third compartment closed, the

order changed after each response. Each fish was kept in the apparatus ten minutes a day and allowed to make the maximum of responses during that period.



FIGS. 15–18

Number 23 was transposed after the eighth day to a combination of dim and dark compartments, the procedure remaining the same. On the thirteenth day the lights were shifted to double-bright and bright, and on the seventeenth day a third light was

introduced. The intensities were now bright, medium and dim. After the nineteenth day the intensities were all increased relatively to double-bright (100-watt) bright and medium. On the

TABLE 1

Special tests given group V

Combination	(di, da, da)	(da, da, bb)	(b, bb, b)	(di, di, m)	(b, da, bb)
Response No. 23	DI	BB	BB	M	BB
	(da, da, da)	(bb, bb, bb)	(bb, m, di)	(m, b, b)	(di, m, m)
	NONE	LEFT	BB	CENTER	BOTH M
	(m, b, bb)	(da, di, di)	(m, m, m)	(m, m, bb)	(da, bb, m)
	BB	CENTER	LEFT	BB	BB
	(bb, m, bb)				
	LEFT				
	(da, b, bb)	(bb, da, di)	(m, da, bb)	(b, m, m)	(da, da, bb)
No. 25	B	DI	M	NONE	LEFT
No. 26	B	DI	M	CENTER	LEFT
	(b, m, da)	(bb, bb, bb)	(m, di, da)		
	M	RIGHT	DI		
	M	RIGHT	DI		
	(da, da, da)	(b, bb, m)	(m, m, m)	(di, b, m)	
No. 25	LEFT	M*	RIGHT	DI*	
No. 26	RIGHT	B	RIGHT	M	

Legend:
di = dim
da = dark
m = medium
b = bright
bb = double bright (100-watt)
* = wrong response
No. 23 to brightest
No. 25 to medium
No. 26 to medium

twenty-fourth day a test was given consisting of varying intensities, relations and positions (see Table 1).

After the eighth day, number 24 was transposed to a combina-

tion of two lights, namely, double-bright (100-watt) and bright; the third compartment was kept closed, the procedure as before. On the twelfth day the lights were changed to dim and dark and a third light introduced after the sixteenth day. The combination was now bright (60-watt), medium and dim. Number 24 was transposed on the twentieth day to double-bright (100-watt), bright and medium.

Subgroup B, including fish numbers 25, 26 and 27, confronted three lighted compartments of the intensities bright (60-watt), medium and dim. The position of a given light was shifted after each response, so that no light-intensity followed itself in a series of trials. The fish were trained to choose the medium intensity, the remaining conditions being the same as for subgroup A. After the sixteenth day the three light-intensities were shifted downward, resulting in the combination, medium, dim and dark. On the twentieth day they were increased in intensity, so that the stimuli were double-bright (100-watt), bright and medium. At the end of the experiment, on the twenty-fourth day, a test was given in which varying intensities, relationships and positions were presented (Table 1).

Results from Group V. The graph of number 23 (Figure 18) was marked in the first part by remarkable gains up to 100 per cent on the seventh day. After the tenth day a slightly lower level was maintained. The plateau at 84 per cent was not broken by the transposition. This plateau may possibly be accounted for as an irradiation pattern from which the animal emerged with insight sufficient to gain a perfect performance after maturation had been resumed. But this improvement was made under the condition of a rigid test in which the relations, intensities and positions of the lights were arranged in unusual novel patterns. (See Table 1.) Thus, number 23 was first given the combination di, da, da, and chose the di, which was correct. Then it confronted the combination da, da and bb, and chose the bb, which was correct. *In fact it responded correctly to sixteen strange and irregular combinations. Each combination was given only once.*

The curve for number 24 (Figure 19) was a curious one in that

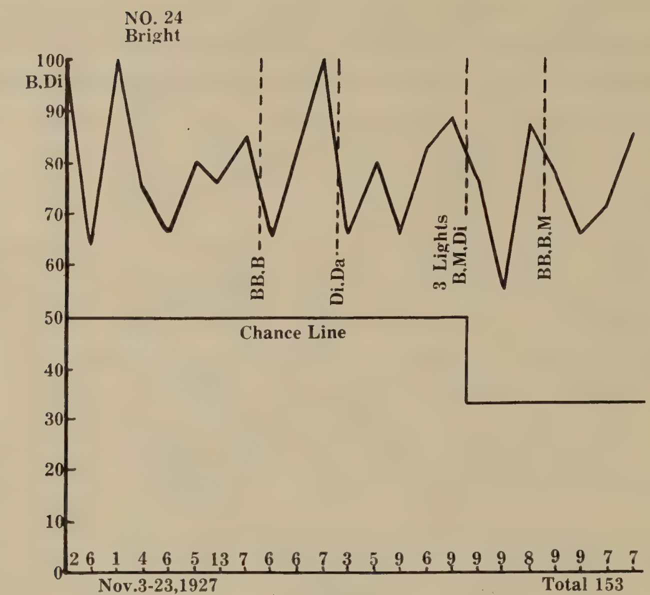


Figure 19

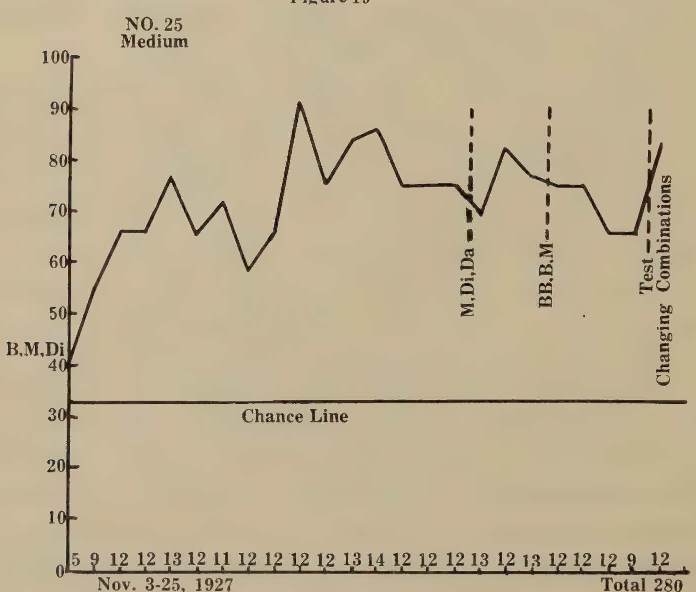


Figure 20

Figs. 19–20

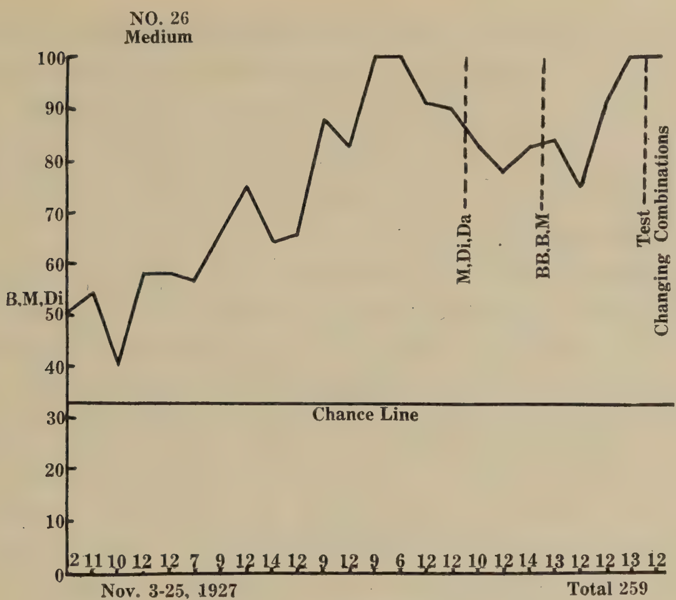


Figure 21

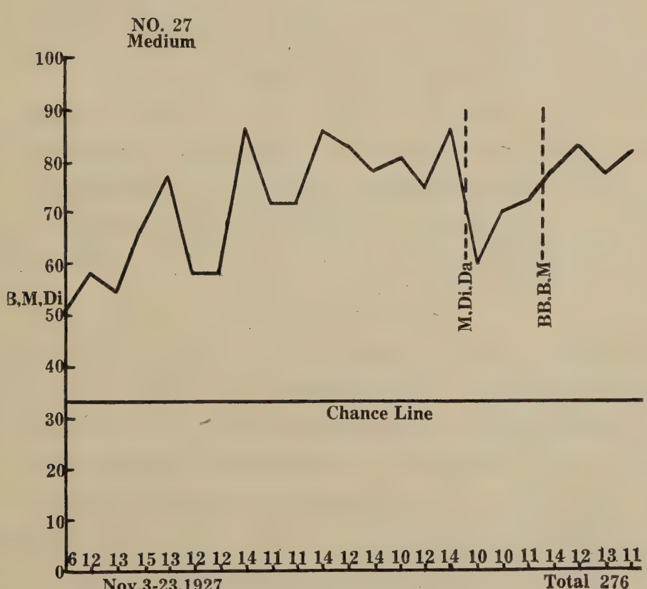


Figure 22

FIGS. 21–22

it started at the 100 per cent mark, probably as a result of chance factors; then it dropped down, fluctuating, except in one instance, around 80 per cent. On the eleventh day a perfect performance occurred which was not repeated before the animal's death prior to the conclusion of the experiment. Obviously one factor in the irregularity of the subject's performance was the relatively few trials made each day.

The graph of number 25 (Figure 20) had a gentle upward slope and although 100 per cent was never reached, all of the curve was well above the chance line. We may suppose that the steep ascents indicate a certain amount of insight, regardless of the fact that perfection was not reached. Yet the animal made a relatively good performance in the final test in which a great variety of novel patterns of stimuli was used (see Table 1).

The curve obtained from number 26 (Figure 21) commenced slightly above the chance line and ascended rapidly until 100 per cent was reached on the thirteenth day. A slight decline, which followed, was regained, after two transpositions, by a steep ascent. This subject evidently showed a remarkable amount of insight into the problem, *making no mistakes on the difficult test that was given at the end of the experiment* (Table 1).

The curve of number 27 (Figure 22) is rather irregular, but, throughout, a general trend can be discerned. The curve starts 20 points above chance and ends about 50 points above.

In the performances of numbers 26 and 27 we again find slight evidence of a preference for 'middleness' in the intensity of lights.

Group VI

The conditions for Group VI were better controlled than those for the earlier groups. Nevertheless, the results obtained from the previous experiments were substantiated. In this experiment three lighted compartments were used, arranged as before, and the lights were the relative ratios, bright, medium and dim. Five intensities of light were employed in the arithmetical progression designated for convenience by the numbers, 0 (no light), 15, 30, 45, and 60 (the upper limit was a 60-watt lamp). These lights were regulated by means of rheostats and were judged by eight human

observers so that there was an approximately equal phenomenal difference between each adjacent pair of light-intensities. The lights were regulated by means of eleven switches, each of which represented a definite combination of three of these intensities, according to Table 2. Thus the experimenter could throw one of these switches and obtain a certain set of three lights; then by throwing another he could vary the light-intensities and also the positions of the lights for the next trial. Therefore, after each response of the fish, the intensity and position of each light, to which it was to respond, was changed, and no two combinations were alike on any one day. A different series of combinations was used each day by beginning at a different point in the combinations from A to K, and also by varying the order.

TABLE 2

Stimulus patterns for group VI

	COMBINATION										
	A	B	C	D	E	F	G	H	I	J	K
Left	30	45	60	15	30	45	60	0	30	60	15
Center	0	15	0	60	0	60	30	30	15	45	0
Right	60	0	45	0	45	15	0	15	45	30	60

Food was placed in each compartment to èliminate all possibility of response on the basis of olfactory cues, and a stick, to use as a shock, was also placed in each compartment, but not in a position visible from the 'choice-compartment.' The fish were allowed to eat in the correct compartment but were immediately scared from the wrong one.

It was suggested in criticism of the preceding experiments that the fish were possibly responding to temperature differences. To test this objection, centigrade thermometers were placed in each compartment and readings were taken after each response, but no change in temperature occurred. This procedure was dropped after a final test in which the compartments were lighted with the various intensities for thirty minutes. Thermometer readings taken before and afterwards failed to show any differences in temperature.

The fish were allowed to make eleven responses a day as a maximum. However, each fish was kept in the apparatus for only ten minutes, and if at the end of that period it had failed to make the

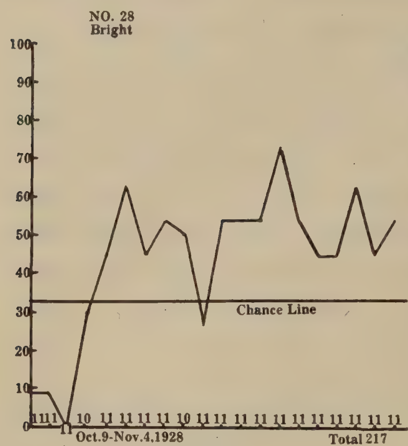


Figure 23

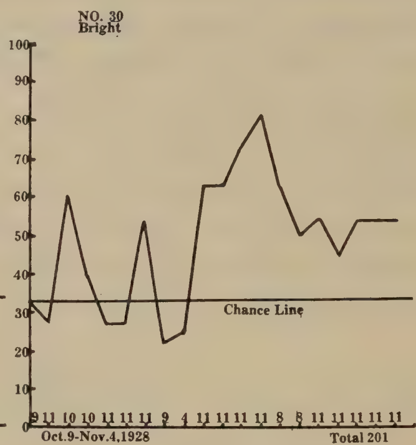


Figure 25

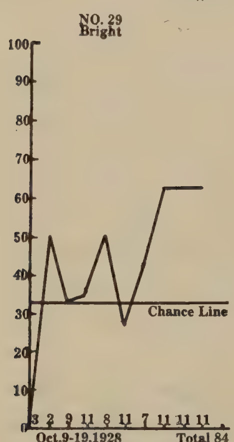


Figure 24

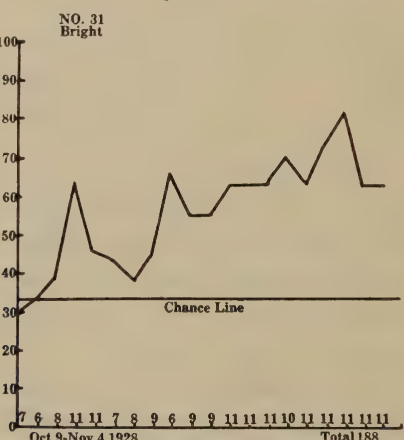


Figure 26

FIGS. 23–26

maximum number of reactions it was removed. The fifteen fish comprising this group were divided into three subgroups according to the stimulus chosen for them. Subgroup A consisted of fish numbers 28, 29, 30, 31 and 42, which were trained to respond

to the greatest intensity in each combination of lights. Subgroup B was composed of fish numbers 32, 33, 34, 35 and 40, selected to choose the middle intensity of light in any set of the series. Fish numbers 36, 37, 38, 39 and 41, making up subgroup C, were taught the lowest intensity of light in any combination of lights of the series.

Results from Group VI. The record of number 28 (Figure 23), although not as good as those of some of the other subjects, was well above the chance line most of the time. The initial ascent was very steep, covering 63 points. The decline that followed was quickly regained in two ascents separated by a plateau. This last ascent was followed by a decline, which was only partially regained before the end of the experiment. The animal undoubtedly possessed a certain degree of insight into the problem, which it acquired suddenly and then retained, for the major part of the curve, following the initial ascent, maintained an approximate level.

The short curve of number 29 (Figure 24) is noteworthy because of its steep ascents. The subject's death made impossible a completion of the experiment.

Number 30's curve (Figure 25) was very irregular and marked by large gains and losses. The first part of the curve evidently shows a lack of the development of insight, but following the ninth day, the problem was more definitely 'perceived,' at least temporarily. Then there occurred a loss which might be explained in terms of an irradiation pattern.

The graph for number 31 (Figure 26) was marked by a gradual ascent to 82 per cent. The few steep ascents indicate, we believe, that the animal had matured with respect to the problem, between trials, sufficiently to approach the situation with increasing insight.

Number 32 (Figure 27) was selected to choose the medium light and began with 100 per cent correct responses, a level which was not regained throughout the remainder of the experiment. The rest of the curve fluctuated around 65 per cent and ascended to a plateau at 82 per cent toward the end of the experiment. It is possible either that the fish had reached its limit

of insight into the problem or that it had 'grown stale.' Number 33 (Figure 28) again exhibited curious behavior by starting at 100 per cent; the entire curve was above 80 per cent. Note that

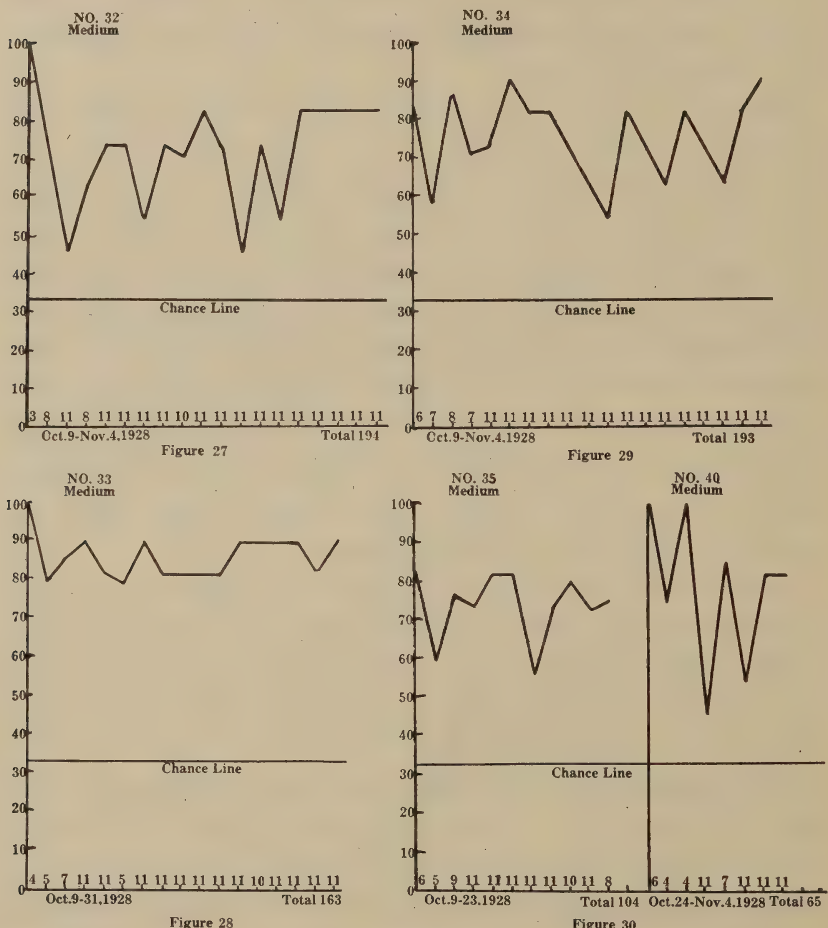


Figure 27 Figure 29 Figure 28 Figure 30

FIGS. 27–30

the fluctuations were of slight extent. Two plateaus are evident, one at 82 per cent immediately followed by one at 90 per cent. Then there was a decline to 82 per cent, and an ascent back to 90 per cent. At this point the animal died. The curve of

number 34 (Figure 29) began at 83 per cent and fluctuated up and down ending at 90 per cent; but it maintained throughout a rather consistent level. No definite gain is evident, but the

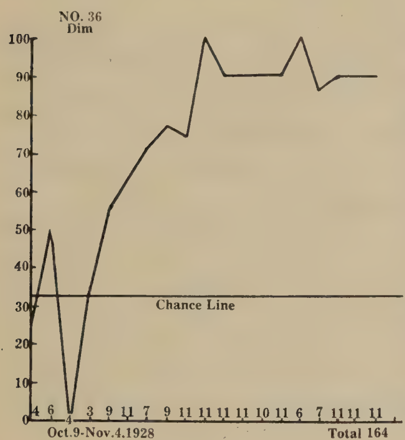


Figure 31

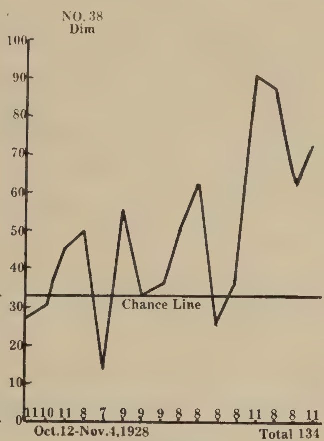


Figure 33

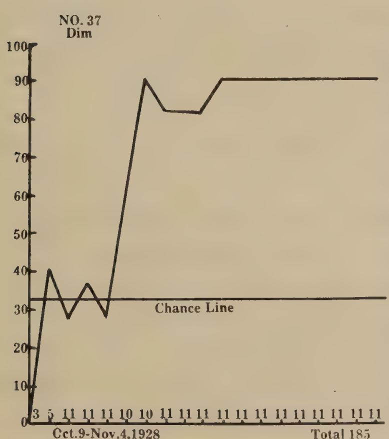


Figure 32

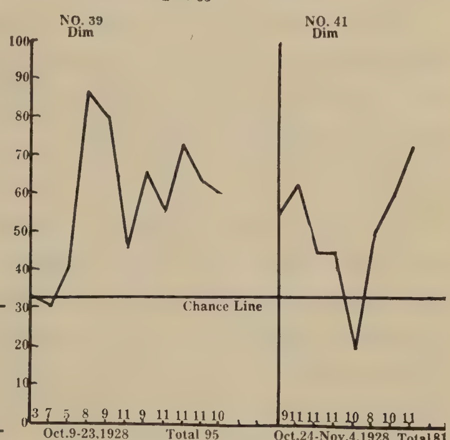


Figure 34

FIGS. 31–34

entire curve is quite an appreciable distance above chance. Number 35's curve (Figure 30) is not long enough, due to the death of the subject, to warrant interpretation; but note that the animal started at 83 per cent. Number 40 (Figure 30) also

trained on the medium light, started at 100 per cent. Its curve is marked by wide fluctuations in the number of correct responses. The interesting behavior of this subgroup will be discussed in detail later.

Number 36 (Figure 31), selected to choose the dim compartment, furnished a curve with a strikingly steep ascent without important further gains or losses, after the initial loss of 50 points. After 100 per cent had been attained there was a loss of 19 points, followed by a plateau at 90 per cent. This plateau probably represents the limit of the animal's insight into the problem.

The curve of number 37 (Figure 32) is noteworthy for the steep ascent of 60 points ending at 90 per cent, which was followed by a plateau at 82 per cent. This plateau was of short duration (three days) and was followed by another plateau at 90 per cent which lasted to the end of the experiment. This last plateau can probably be attributed to the fact that a maximum of insight into the problem had been reached.

Number 38's performance (Figure 33) was very irregular, characterized by steep ascents and declines; however, there was a general trend upward, which shows some evidence of insightful activity, and a mediocre mastery of the problem for the first several days. The steep ascent that followed is worth noting.

The curve of number 39 (Figure 34) was short because of the subject's death, but one feature is worth mentioning. The steep ascent in the first part of the curve was followed by a steep descent. This is correlated with the fact that on the fifth day the animal was hit by the 'shock stick' and injured. The performance of number 41 (Figure 34) is also inconclusive because of the animal's illness and death.

We have already noted some evidence for the fact that the goldfish preferred lights of medium intensity to lights of extreme high and low intensities. In Group VI, *where all the lights were constantly changing in absolute brightness, this preference seemed all the more evident.* One is inclined to suspect that shifting combinations 'brought out' or emphasized 'middleness.' This point will be discussed more fully in a subsequent section of the paper.

QUALITATIVE RESULTS

In presenting the results obtained from these experiments, certain facts come to light that cannot be presented merely in a quantitative manner. It will be our purpose here to present certain of these typical reactions, many of which were frequently repeated by several different subjects.

What might appear as the correction of a wrong response occurred in all the fish except those of Group I. That is, after having entered a wrong compartment, the fish would, on being scared by the stick, dart immediately into the correct compartment before a change in the combination of lights could be made. This performance took place in some subjects three or four times a day, and in one subject, forty-two of these reactions (out of one hundred thirty-one) were recorded during the entire course of the experiment. It was decided not to regard these responses as correct, for the reason that there was no way of determining definitely whether these were actual corrections of errors or only results of the shock. The former seems the more plausible interpretation because of the frequency with which the reactions occurred, and also by virtue of the fact that in a large number of cases the correct compartment was not opposite, or in a direct line with, the wrong one, but to one side. Thus it was necessary for the animal to dart out and *turn*, in order to enter the right compartment. *It also should be noted that very rarely did the animals dart from one wrong compartment into another wrong one.*

It was observed, during the experiments, that a fish often went to the door of a wrong compartment, remained there a few seconds, looking in, either quiet or swimming slowly back and forth. Then it would swim quickly to the correct compartment and enter it. In some cases a complete circuit of the compartments was made before entering the correct door. Another type of response took place frequently, namely, stopping at the door of a correct compartment only to back in and out, finally going inside. At times it seemed as if the fish was afraid of the light, but this behavior occurred quite as frequently with one intensity as with another. After edging out of a compartment, one fish *backed*

into the same compartment—a correct response—although a change in relative intensity of the light had taken place.

Since more careful qualitative data were collected for the last group, they will be discussed here apart from the preceding groups. One subject, early in the experiment, *made five successive correct choices, each one to the right of the preceding one; then the sixth position, which was to the left, was responded to correctly.*

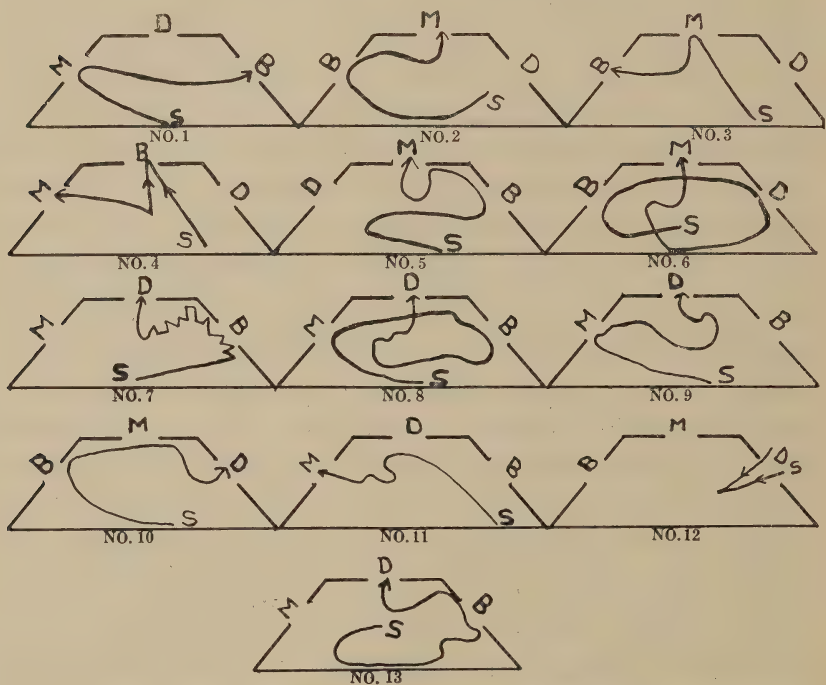


FIG. 35

In one instance number 30, which was to choose the bright light, swam toward the medium light, 'nosed into' the door, and then darted into the correct compartment which was on the opposite side. (See Figure 35, number 1.) Number 30 appeared 'excited' in the first part of the experiment and swam back and forth without stopping to choose, thus making a large percentage of errors. In another instance this fish partly entered

the bright compartment twice, which was correct, but finally went to the medium light. At another time it went halfway into the bright compartment (correct) but backed out and chose the medium.

On the first day, number 32, which was being trained to choose the medium intensity, swam toward the bright light as if to enter, but turned and chose the medium (see Figure 35, number 2). At another time number 32 swam straight for the medium light (correct) but backed out of the door and chose the bright compartment (see Figure 35, number 3).

Number 33, which was to choose the medium intensity, swam straight toward the bright light (wrong), entered halfway, swam backward, turned and chose the medium compartment. (See Figure 35, number 4.) On the seventh trial, number 34, choosing the medium intensity, headed for the dim, changed its course and headed for the bright, turned and finally chose the medium compartment (correct; see Figure 35, number 5). In another instance this same fish swam toward the bright light, changed its course, made a complete circuit of the 'choice-compartment,' ultimately making a correct choice (medium; see Figure 35, number 6).

Fish number 36, which was trained to choose the dim light, swam in zigzag fashion as if to go into the bright or the dim compartment, and finally chose the dim (correct; see Figure 35, number 7). At another time it swam toward the medium light, changed its course and made a complete circuit of the 'choice-compartment,' finally responding correctly (dim; see Figure 35, number 8). In still another instance, it headed for the medium compartment (wrong), suddenly changed its path at the door, swam to the center of the 'choice-compartment' and went to the dim light (correct; see Figure 35, number 9).

Number 37, choosing the dim intensity of light, swam toward the compartment of medium intensity, did not enter, but swam on to the dim compartment (correct; see Figure 35, number 10).

Number 38, also trained to choose the light of least intensity, headed toward that intensity but changed its course and chose the medium light (wrong; see Figure 35, number 11).

Number 39, trained to choose the dim light, in one instance swam toward and almost into the medium and bright compartments several times, each time backing out again. Then it swam toward the dim light several times, backed out each time, and finally chose the medium compartment (wrong). At another time this subject was so frightened by catching it on the net before the day's experiment began that it lost its orientation and for several trials swam 'blindly' from one compartment to another. Shortly afterward, this fish kept facing the dark door (correct) but would not go in. It headed finally for the medium compartment, where it swam in and out four times, never going entirely inside. It ultimately chose the dark compartment (correct). At another time, this fish headed into the dark compartment six times; each time it backed out again, and entered on the seventh trial. A series of tests was arranged so that the correct compartment was in the same position twice in succession, although the intensities of the lights were changed. Number 39 left the compartment it had just entered, and when the change in intensities was made, backed into the same compartment again (correct; see Figure 35, number 12). On the following trial this fish made a circuit of the 'choice-compartment,' starting from the center; it then headed toward the bright light, changed its course and chose the dim light (correct; see Figure 35, number 13).

It was noticed that in Group VI, subgroups A and C made a majority of their errors by entering the compartment of *middle* intensity. Subgroup B, choosing the middle intensity, made practically perfect performances the first time, and generally became worse with further repetition (three out of five fish starting at 100 per cent). This same result was noted but to a less extent in Groups III and V.

Rarely was the behavior of any fish of the kind that could easily be classified as random. On the contrary its activities revealed all the characteristics of 'deliberateness' of a sort. Hesitations, changes of direction and changes in speed of movement seemed to be made with reference to a goal in the light of the total stimulus-situation. Especially is this borne out by the fact that when the animals 'hurried' into a given compartment, in the

early stage of the learning, they made errors more frequently. The majority of correct 'choices' were made 'slowly' and after a brief pause or delay in movements. We suggest that this delay represents the time consumed in the development of an insightful or newly organized response with respect to the existing situation. That insight into a given situation requires time for development is a well known fact of human experience. It is not unlikely that an analogous but simpler procedure obtains even in the lower animals.

GENERAL DISCUSSION OF RESULTS

No absolute uniformities can be discerned from a critical examination of the various graphs, but a number of general characteristics, which raise certain problems, deserve notice. The curves (scores) for the animals trained to choose the bright intensity seem to be lower than for the other groups. This is especially true in the last group (VI) where the graphs are particularly low; however, they are all above the chance line. This lowness of score may have been caused, in the last group, by a tendency of the fish to avoid the brighter intensities, but as this tendency was not observed in the preceding groups, to so great an extent, it may be concluded that the brighter lights presented a more difficult problem by introducing steps in intensity that were less easy for the fish to perceive (Weber's Law?) although the upper intervals were roughly equal to the lower ones for human beings. For the same reason it may be assumed that the dim-light problem was learned more readily, *not because the fish were negatively phototropic*—there is no evidence of this fact from our experiment—*but because the problem was easier for the fish to solve.* If this is true, it would naturally follow that transposing upward was more difficult for the fish than transposing downward.

As was mentioned already, the fish of the last group, that were to respond to the medium intensity, made very few errors at the outset (three out of five starting at 100 per cent) and in some cases repetition of stimuli conditioned an increase in errors. (This can readily be seen from the graphs of numbers 32, 33, 34, 35 and 40.) This was not so obvious in the fish that responded to the

medium light in the preceding groups where the absolute intensity of the medium light was not constantly changing. It was also noted that the fish of subgroups VI A and VI C, trained to choose the bright and dim intensities, respectively, made a majority of their errors by entering the compartment of medium intensity. We may conclude, therefore, that these fish were perceiving 'middleness' in intensity, not an *absolute* middle intensity. This fact, if true, can be interpreted in the light of the law of least action, a principle suggested, among others, by Helson[26] in connection with the behavior of the white rat, and adopted by Wheeler[27] as a general working hypothesis in psychology. It is a law implied in all configurational activities *if those activities are described in dynamical terms*, and is implicit in much of the *Gestalt* literature, especially in discussions of 'closure phenomena,' resolutions of tensions in the direction of equilibrium, and the like.[28] We may suppose in the light of this law, that tensions are set up in the fish by the extreme elements of brightness and dimness and to release these tensions the animal responds in the most direct way possible by choosing the middle intensity. In the presence of extreme intensities the middle light, whatever its absolute brightness, becomes the goal the reaching of which resolves the animal's tension. The middle intensity, by virtue of its position in the scale or range of intensities, functions as the remote end with reference to which the closure phenomenon occurs.[29] Extreme intensities disequilibrate the energy of the neuromuscular system in such a way that an equilibrium is reached in the line of least action in selecting a light of middle intensity. In other words, the light of middle intensity, in this situation, functions in a manner not unlike the center of a gravitation system, in that it becomes the point of reference with respect to which action occurs within the system. The lights of extreme intensity correspond roughly to stresses outside the center of the gravitation system,

[26] Helson, Harry, "Insight in the White Rat." *Jour. of Exper. Psychol.*, 1927, Vol. 10, 388.

[27] Wheeler, R. H., *The Science of Psychology.* Crowell, 1929, 79–85, 125, 311.

[28] Cf. Koffka, K., *Growth of the Mind.* Harcourt, Brace, 1924, 97, 103–108, 205.

[29] Cf. Koffka's account of eye-movement, *loc. cit.*, 72 ff.

stresses which also function in conditioning the path of least action.[30] It may be supposed that, in spite of the fact that the behavior of the fish follows a dynamical law, its activities are insightful when we define insight as the process of making an organized or structured response on the level of conscious behavior. Organized response means, at this level, the perception of total situations. Therefore, perceiving 'middleness' in a combination of lights, is at the same time an exhibition of insight and an illustration of the law of least action. Indeed, we may presume that the latter assertion is true of insight wherever found. In short, to describe intelligent behavior in terms of least action is merely to describe it in terms of a basic principle, a principle, however, which need not be interpreted as a mechanistic one simply because it is 'physical.'[31]

As the experiment progressed, certain other goals (principally food) than the middle light were set up, in subgroups VI A and VI C, which inhibited this response, for the 'medium' fish became worse, at least temporarily. This apparently anomalous state of affairs may have been caused by the fact that the 'medium' fish were not responding to a food-goal at the outset. (The fish frequently did not eat after entering a compartment.) Before the food-goal functioned with respect to the medium light, these fish became hungry, perhaps, and started to choose any compartment. Thereafter, until they perceived the food-goal in relation to the 'medium' compartment, they made relatively inaccurate responses. Moreover, in connection with the punishment it was noted that all the fish in the last group became less afraid of the stick as the experiment proceeded. This fact would, under the conditions just mentioned, delay learning in the 'medium' fish. A similar conflict of goals and adaptation to punishment might have occurred in subgroups VI A and VI C.

Also in connection with the subjects of Group VI, that chose the medium light, it was noted that the curves fluctuated around a median point which was fairly high in practically every case. It may be suggested that this average represents the point at

[30] See Wheeler, *loc. cit.*, 125.

[31] Wheeler, *loc. cit.*, 79, 83, 126.

which equilibrium was re-established between stresses within the fish and the forces of the stimulus-pattern. Individual differences between the fish conditioned the average level.

A discovery was made after an examination of the data, namely, that the largest number of errors was made when the correct compartment was in the center of the three positions. This was particularly true in Group VI. The explanation suggests itself that the animals did not so readily perceive the center light in its relation to the other two as they perceived the two side lights in their relations. The data show a discrimination between the two side lights that is far above chance. However, owing to the fact that this is not a universal occurrence because of the number of correct responses to the center light, it is merely concluded that the center position was the hardest one for the fish to choose. Possibly the center light was more often farthest from the fish when he was placed in the 'choice-compartment.' In the case of the subjects that responded to the bright light, it appeared that not only was the foregoing suggestion borne out, but it seemed all the more obvious when the 60-watt intensity occupied the center position. However, by the use of the 60-watt lamp we may be running into a complication, namely, Weber's Law, mentioned previously.

From time to time we have emphasized the development of insight in connection with the interpretations of the graphs. We defined insightful activity, in the introduction, by certain criteria. Various criteria have been enumerated by different authors but most of them are only slight variations of the following: Response to the whole, or to a part in light of the whole (configurational response); transposability of general conditions from one problem to another problem; and modifiability of behavior to meet new situations correctly the first time. The development of insight is not the result of a mere 'trial and error' performance, for it is generally quite sudden. This is illustrated by the steep ascents in so many of the learning curves. These 'flashes' or sudden developments of insight are sometimes preceded by a decline or a plateau, caused perhaps by 'irradiation,' a phenomenon described by Snoddy.[32] It is observed in behavior as a loss of

[32] Snoddy, G. S., *loc. cit.*

co-ordination, and introspectively as a lack of perception of detail. If irradiation was operating in our experiment it would probably result in an inability of the fish to perceive one light in its relation to the total pattern, or in other words, in a failure to exhibit insight. It must also be assumed that configurational responses of the fish in a learning situation are at first relatively unstable, as a consequence of which in one trial the fish will make a relatively good performance, whereas in the next it may show a decided increase in the number of errors. But this need not be considered a loss of insight; rather, a consequence of differences in difficulty of forming similar configurations at different times, caused by conditions not apparent to the human observer, or not under control. For example, the successive stimulus-patterns were probably not of the same difficulty of perception; the fish may not have been responding under equal tensions (hunger, fear of punishment) on different days, hence their responses would not be uniformly effective; tension was not constant in any *one day's series* of trials, caused by lessening of hunger. Difficulty was experienced in keeping the fish in a healthy condition, especially with considerable handling; different positions in the 'choice-compartment' from which the animals made their choices involved different perspectives and hence different relationships; varying speeds with which the responses were made altered the stimulus-patterns and with them the difficulty of the relationships to be perceived; at certain times the animal may not have seen all of the lights in one configuration because of his position in leaving a given compartment; and finally, maturation, which seems a far better explanation of learning than changes effected by repetition and satisfaction, is probably not a steady process.

When we consider such extenuating circumstances as these, our qualitative results reveal compelling evidence that the goldfish did not learn by 'trial and error' in the usual sense of the term (see Figure 35).

In the learning process the animal responds to the pattern which it sees, in the light of the insight which it possesses. This response involves a perception of the goal in its relation to the *total situation.* Insight in the fish develops, we may suppose, as the

result of a maturation process; thus the animal can respond to a gradually more complicated stimulus-pattern.[33] In so doing it reduces the number of its errors. Its response, regardless of the amount of insight, always takes place in the line of least action, and is conditioned by the tensions set up in the animal through external stimulation. The response ends with the establishing of relative equilibrium between stresses within the animal and external forces acting upon it. Although this tension-relieving process goes on, the errors at the beginning of the experiment fail to relieve the tension and to restore the animal's balance with its environment. Under the continued tension, insight into the problem develops until the animal can restore equilibrium by making a correct response. In this way the learning as a whole is a continuous process of resolving a tension by reaching a goal. Insight is a term which describes this process at the level of conscious behavior.[34]

When this manuscript was ready for the press a study by Warden and Rowley[35] appeared in which the authors vigorously attack configurational investigations of learning. Their arguments are sufficiently superficial and faulty to warrant special consideration. Now that the *Gestalt* psychologists have made systematic use of the so-called 'relational judgments' and have set about intensively to devise experiments in connection with this

[33] Here we are using maturation in the sense in which the term was used by Koffka, *Growth of the Mind*, 249, but more especially as used by Coghill, *Anatomy and the Problem of Behavior*, Macmillan, 1929. The problem of maturation is implied in Köhler's theory of the 'non-process change.' Cf. Koffka, "On the Structure of the Unconscious," in *The Unconscious, a Symposium*, Knopf, 1928, 43–68, also Wheeler, *op. cit.*, 319, 321, 290–300. Wheeler has developed at length the relative merits of the theories of learning by exercise, or by trial and error, and learning by maturation.

[34] While we have assumed that the fish responded to brightness and not to color, the fact remains that dimming the light by means of rheostats made the lights more yellow. It is clear, however, that the fish were responding to one detail of the stimulus-pattern in its relation to other details whether the stimuli were degrees of brightness or yellowness. Additional experiments are under way in which it is hoped to determine whether hue operated along with brightness.

[35] Warden, C. J., and Rowley, J. B., "The Discrimination of Absolute *Versus* Relative Brightness in the Ring Dove, *Turtur Risorius*." *Jour. Comp. Psychol.*, 1929, Vol. 9, 317–338.

problem, Warden makes light of their work even to the extent of charging that "the work of the *Gestalt* group on this point renders their data highly questionable if not entirely worthless" (322). He points to several American studies, beginning with Kinnaman in 1902, in which relative discriminations were discovered more or less incidentally. Regardless of the question of priority of discovery, the history of psychology in this country, and the slight systematic importance ascribed to these judgments by the animal experimenters to which Warden refers, prove that the prevailing concepts of animal learning have been atomistic and associational. Warden seems to accept the incidental findings and unsystematic results of American investigations as evidence in favor of the conclusion that relative discriminations are the rule rather than the exception, and are easier for the animal to make than 'absolute' judgments. It seems rather inconsistent to regard relatively incidental evidence as important and the systematic results of the *Gestalt* investigators as unimportant and worthless! Furthermore, now that the 'relational judgment' has come into its own through the efforts of *Gestalt* psychologists, American experimentalists who noticed and neglected these judgments are howling for credit, but the credit is that of finding something of extreme systematic significance without knowing it. Such a priority as this is not especially to be craved.

Warden levels, first, the charge against the *Gestalt* psychologists that they did not exclude the experimenter from the situation implying, of course, because American investigators have interpreted animal learning in terms of 'trial and error,' that the latter have succeeded, at least more effectively, in ruling out the experimenter. There is good reason, however, for the claim that the trial and error concept, and the implication of absolute judgments, *are far more anthropomorphic than an interpretation of animal behavior in terms of insight.* The reason is this: Before an animal's performance can be regarded as an exhibition of trial and error it is necessary to reflect that when we, as human beings, commence a given learning process, we are less efficient than at a later stage in the learning. We are comparing an initial with a final and perhaps a perfected mode of response. We are applying

a standard (to the entire learning process) that is conceivable only after the act is perfected. What could be more anthropomorphic? Presumably only an intelligent being can perform such a feat! Moreover, a learner might think that he was doing very well, while an observer of superior intelligence might regard him as very stupid. To consider a learner as stupid, a judgment possible only on the basis of a *higher standard than his*, or in other words, to consider his performance as a trial and error one, is certainly to apply to the learner a foreign, arbitrary and highly intellectualized standard. When applied to animal learning it is *not only an anthropomorphic standard of evaluation* but one possessed by a human being *expert in the task imposed upon the learner*. The interpretation of insight is not open to this objection because insight can be as lowly as we choose to make it. In our opinion it is the American associationist and not the German *Gestalter* who has been so unsuccessful in excluding the experimenter from the situation. The concept of insight, rather than the concept of trial and error, follows the law of parsimony.

Warden charges the *Gestalt* psychologists, second, with the error of not checking their results, because they rewarded their animals during the transposition experiments. This, it is claimed, might force the animals to make relational discriminations when previously, they might have been making absolute judgments. In other words, such transposition experiments do not prove that all discriminations are relative.

The value of the control that Warden suggests seems entirely to be overestimated. If his fears were justified one would expect, upon transposing an animal, that it would revert to its original score in the learning process, something that occurs only in extremely rare instances and is easily accounted for by chance variations in the conditions of experimentation. In all of our experiments on transposition we have found, in spite of continued rewarding for successful choices, that learning is faster after the transposition than before it, providing the transposition comes early in the course of the learning, where rapid progress (as measured in time) is possible. To make a large percentage of first responses correctly after the transposition, or even to learn the

transposition problem in a day or two, when absolute judgments were made prior to the transposition, would involve a degree of intelligence which we might hesitate to attribute to human beings! Yet, if we follow out the logic of Warden's objection we would be forced to just such a conclusion. The animal would have to think: "Well, the experimenter has changed the situation to one in which he wants me suddenly to make relative judgments instead of absolute ones!" To be sure, transpositions frequently disturb the animal, doubtless *because the total effect of the change is noticed; the summated brightness or size or form is altered.* Such a change is frequently confusing even to a human being! On the other hand, there are many cases in which transpositions result in no decrement, and even in further progress at once. We object to the assertion, therefore, that the *Gestalt* experiments are practically worthless on this point.

Again, Warden cites the work of Gayton[36] as possible evidence in favor of absolute factors. White rats learned to choose food from the brighter of a pair of stimuli, dim and medium, and transposed to a dim and bright, but the responses to the lighter of the second pair were less frequent than the responses to the lighter of the first pair. This fact, however, does not prove the existence of absolute factors any more than it indicates that a smaller interval was more familiar and therefore represented an easier problem, under the conditions, than a larger interval.

Warden's own work, performed on the ring dove, aimed to throw light on the question whether absolute discriminations are difficult for an animal to make, as compared with relative discriminations. He used a certain medium grey as the cue for food and paired this grey first with a lighter and then a darker one. The problem for the dove was to choose the medium whether it was paired with the one or with the other. He had only two subjects, one of which failed to master the problem. The other was very slow; it did not reach 70 per cent in correct choices until after the 600th trial and attained a score of 80 per cent around the 850th trial. Warden's tentative conclusion is that relative choices seem to be easier

[36] Gayton, A. H., "The Discrimination of Relative and Absolute Stimuli by Albino Rats." *Jour. Comp. Psychol.*, 1927, Vol. 7, 93–107.

than choices based on absolute factors, but his method does not indicate positively, even to the slightest degree, that the successful dove was choosing upon the basis of absolute stimuli. On the contrary, the long time required for one of his subjects to learn the task, and the failure of the other subject, *might more plausibly lead to the opposite interpretation.* The real problem was: When the medium grey appeared with the lighter one, the darker was correct; *but* when it appeared with the darker grey, the lighter was correct, a hard problem even for a child! *Not an absolute judgment but two relative judgments forming a complex temporal configuration* were required of the doves. Moreover, a grey paired with a lighter one looks darker than when paired with a darker grey, at least in the case of human observers. The standard, as such, therefore, might have looked different to the birds, depending upon the variable which appeared with it. Warden is hardly as free from preconceptions and systematic prejudices as those whom he criticises.

CONCLUSIONS

The following conclusions seem justified by our experimental results:

1. Goldfish readily learn to discriminate between different degrees of light intensities (possibly degrees of yellow).

2. These animals seem able to detect a 'constant relationship' between the lights when the intensities are shifted upward or downward, thus indicating that their responses are configurational, or structured. *This fact held when the intensities of the lights were constantly changing, that is, when transpositions were made after each trial,* so that no combination occurred twice in the same day. The variables were: Position, brightness of individual lights and degree of difference between the lights.

3. There is some evidence that steps in brightness toward the upper range of intensities were harder for the fish to detect than steps toward the lower end of the range.

4. There is evidence that the light of middle intensity, especially under the conditions of constant transposition, functioned as the goal, independently of other goals, or until other goals

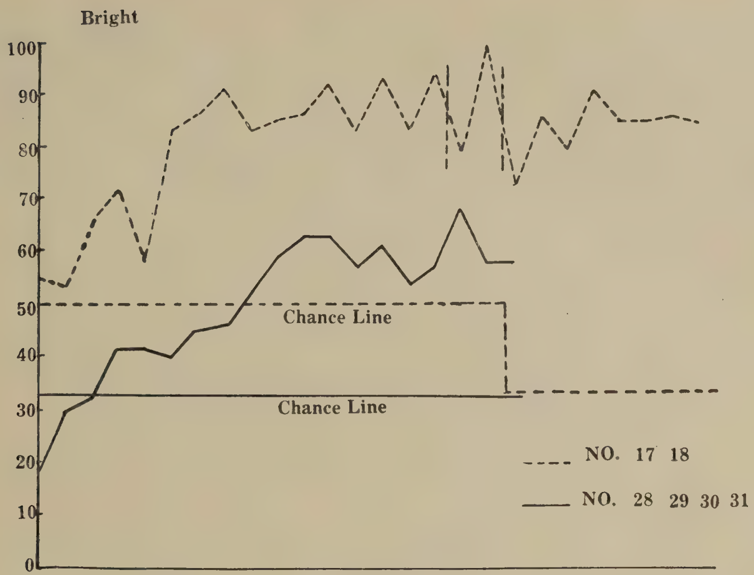


Figure 36

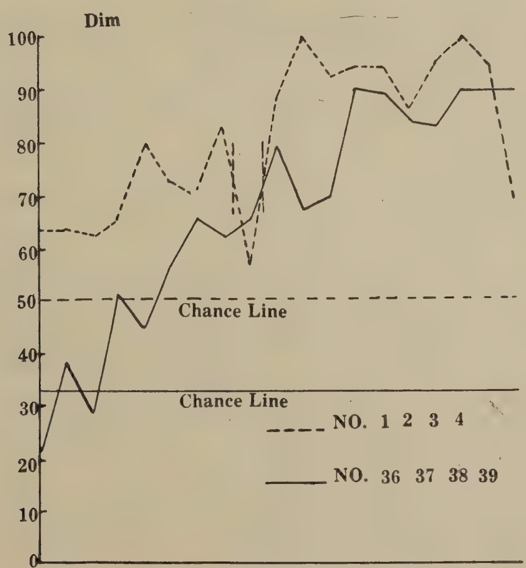


Figure 37

FIGS. 36–37

were established, thus indicating that the fish were neither negatively nor positively phototropic. The 'middle' or 'center' light, between extremes of strong and weak stimulation, represents the center of an equilibrated system, like the 'center' of a gravitation system. By this is meant that the 'middle' light functions as the goal the reaching of which, other things being equal, resolves the tension under which the animal behaves.

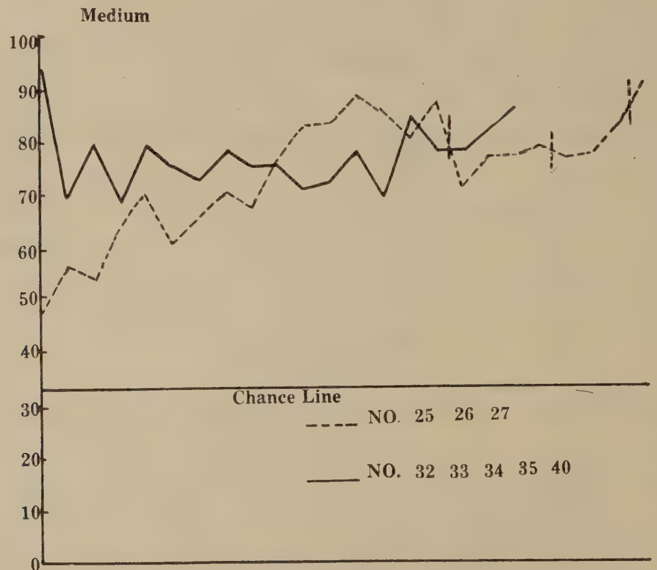


Figure 38

5. We have described learning in the goldfish in terms of insight and maturation rather than in terms of 'trial and error'. *The usual criteria of insight are found in the behavior of the goldfish.*

6. We have interpreted learning in the goldfish in terms of the general law of least action.

For the sake of completeness, average curves are here appended (see Figures 36, 37 and 38).

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BY

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J. F. DASHIELL

University of North Carolina

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Constructive Suggestions

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PRELIMINARY EXPERIMENTS

I. EXPERIMENTS WITH CHANGING MAZES

In some earlier experimental work (1920a) the writer had observed that the white rat tends to form a habit of orienting in a general direction when in a series of trials it is run through mazes having certain spatial features in common. In that study hungry animals were run once per day through a series of mazes that varied in pattern from day to day but that were in essence variants of one maze. Maze *1* in Figure 1 was the original design; maze *2* was a re-construction of *1* made by changing some of the partitions; maze *3* was a further re-construction; and so on throughout a series of 25 daily trials. The animals run through the mazes made records which showed irregular but definite reductions of errors, hence some sort of learning; and—what is more to our interest here—they showed a greater avoidance of entrances into blind alleys that happened to be turned away from the general direction of the food box than they did of entrances into alleys turned toward the food box. Figure 2a shows, trial by trial, the total number of entrances into blind alleys of the two types, each divided by the number of blind alleys of each type offered. Averaged totals showed that blind alleys turned in the food box direction were entered on an average of 4.58 times, whereas those turned in the reverse direction were entered on an average of 1.59 times.

Some five months later, the whole experiment of which the above-described series formed a part, was repeated for purposes of checking. The data from the series of 25 changing mazes bore out well those of the earlier experiment, as may be seen in Figure 2b. Averaged totals showed that blind alleys turned in food box direction were entered on an average of 5.12 times, whereas those turned in the reverse direction were entered on an average of 1.57 times.

Now certain features of the mazes were identical or were similar throughout the series. The outside dimensions remained identical; the entrance door was always on the same side of the maze, and the exit door was always on the same side (opposite to that on which the entrance door was placed); and the position in the experiment room was a constant one.

Summarizing, in these two series of 25 runs in changing mazes,

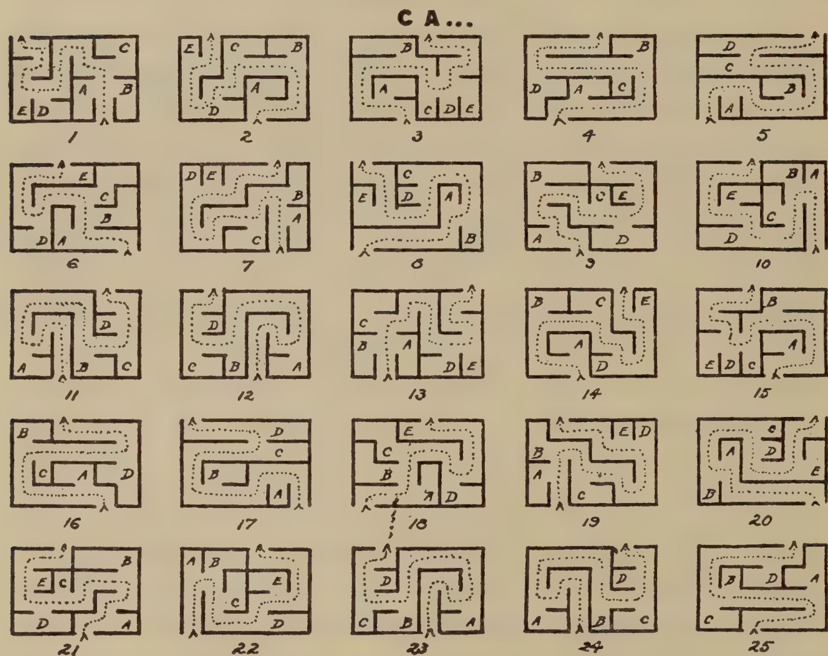


Fig. 1. A Series of 25 Different Successive Settings Used with a Given Maze

the animals seemed to be slowly developing some rough orientation that was increasingly responsible for the character of their errors.

Whether the orientation was established with reference to intrinsic features of the mazes—side of entering and side of exit from maze being constant—or whether it was with reference to landmarks furnished by visible distant details in the laboratory

room, was not clearly indicated. (For reasons that need not be detailed here, olfactory stimuli and visual stimuli from within the maze were ruled out as entirely negligible.) Again, as the maze patterns had not been arranged so as to be run through in different directions in different trials and thus to be the reverse of each other, one could not be sure that differences in the detailed

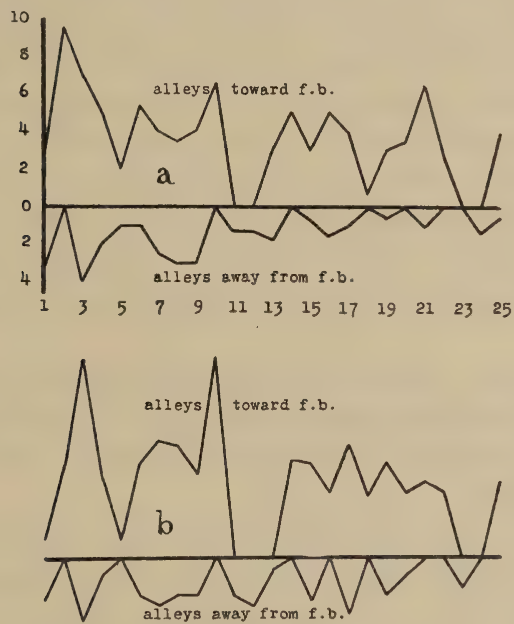


Fig. 2. The Total Number of Entrances Made on Each Trial (i.e., in Each Successive Maze-Form Shown in Figure 1) into Blind Alleys Leading toward Food Box Position and into Those Leading Away from it, Each Divided by the Number of Blind Alleys of Each Type Offered on the Respective Trials

a, first series of experiments; *b*, second series

peculiarities of alleys, turns, etc., might not be partly responsible for the demonstrated difference between the tendency to enter the backward-turned and the forward-turned alleys. Certain types of blind alleys might be more readily entered than others; some spatial articulation of blind alley with true pathway might make the former more entered, etc. (The latter question led the writer

incidentally to an experimental demonstration of the importance of these peculiarities in maze construction (1920b), which need not be described here.)

II. EXPERIMENTS WITH MAZES WITH F-B PAIRED ALLEYS

From the foregoing experiments it seemed that direction-orientation in some manner was set up as rats traversed mazes having certain spatial elements in common. It appeared justifiable then to assume that direction-orientation might operate as a contributing factor when rats were learning the traditional type of fixed maze; that in addition to the fixation of tendencies to make specific turns at specific points, to run for specific distances in specific straightaways, etc., there might be occurring the establishing of orienting tendencies that would contribute to the learning of the pathway by, say, facilitating turns in the direction of the orientation and by inhibiting turns in the reverse direction.

Whether such orientation function does contribute at all in learning a fixed maze, became then our next problem; and the theoretical questions as to the essential nature of such a function were postponed.

1. In 1924 rats were trained in two fairly simple mazes of 8 blind alleys each. In order to eliminate any differences in special directing influence from blind alleys differently constructed, the alleys were located in pairs so that for each alley that turned off the true path in the general food box direction or "forward" there was placed opposite it an alley of similar pattern but turned the reverse of the general food box direction or "backward." No other blind alleys were provided. In order further to eliminate any differences in intrinsic features of the two mazes that might favor more turns into the "forward" alleys or into the "backward" alleys in either maze, it was arranged to use the same maze in two different problems—as a maze in which the animal ultimately finds its reward located forward and as one in which it finds it located backward.

Figure 3 shows the pattern of the double maze used. On opposite sides of the true pathway, which is identical for the two

learning problems, the "forward" and "backward" blind alleys were paired; as indicated by letters "*F*" and "*B*" respectively. At the end of the maze proper, the true pathway was divided; so that with a door closed at x or at y the animals could find their food at food box f or at b, as was required for the two problems.

Subjects. The animals used in all experiments to be reported throughout this paper were from a colony locally maintained and originally derived from stock obtained from the Wistar Institute. The usual diet was bread soaked in milk, with a few drops of cod

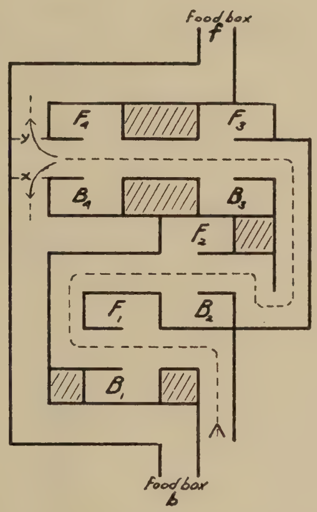


FIG. 3. THE DESIGN OF THE F-B MAZE

liver oil; to which vegetable and meat scraps were added at irregular intervals.

Apparatus and materials. With one exception, to be noted in the proper place, all the mazes used in the studies to be reported here were constructed of galvanized iron partitions set upon cork linoleum floors with wire mesh or glass tops. The method of construction was a multiple-unit take-down system, in use by the writer since devising it in 1918. It has been described elsewhere. (Cf. Stetson and Dashiell, 1919.)

In this series of experiments two small groups of rats were

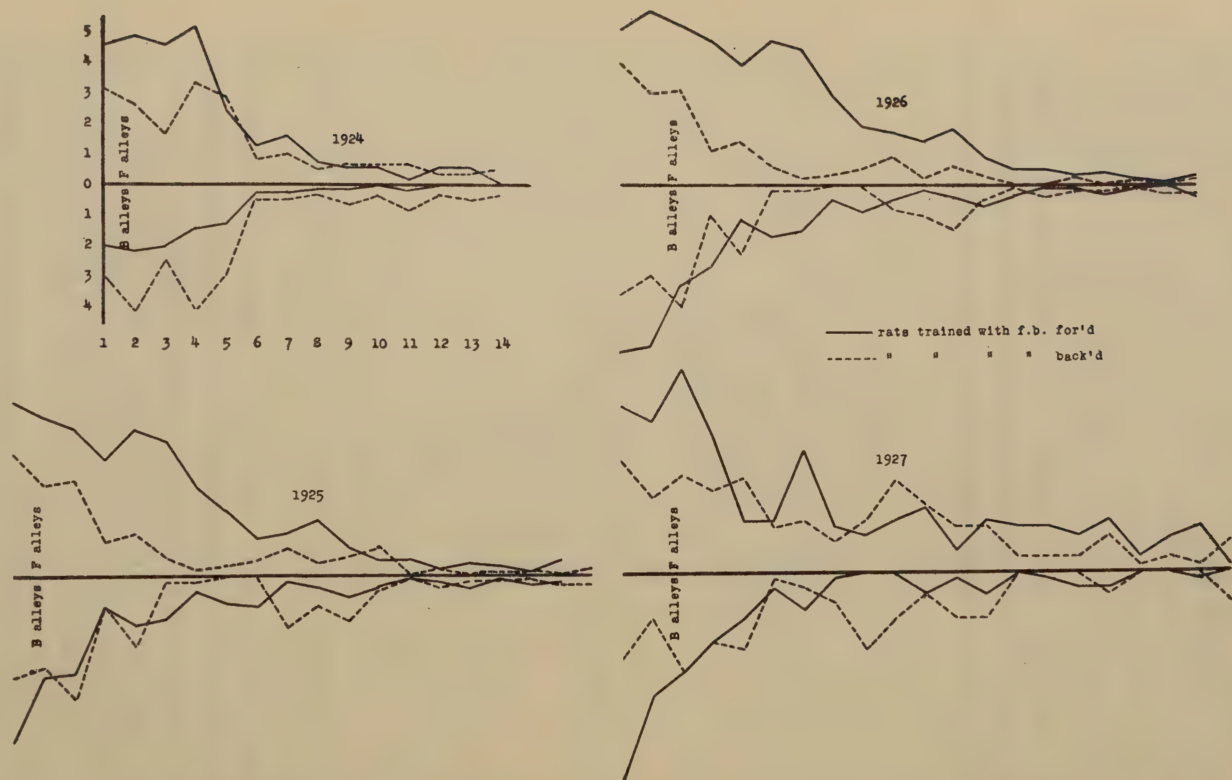


Fig. 4. The Total Number of Entrances Made on Each Trial into Blind Alleys Leading in a Forward Direction, F, and into Those Leading in a Backward Direction, B

Readings above the horizontal axis represent entrances in F alleys; those below the axis, into B alleys. Continuous lines represent scores for animals being trained with food box in the "forward" position; broken lines, scores for those being trained with food box in the "backward" position (f and b in figure 3). Results are furnished for experiments conducted in four different years.

used: one of 7 rats trained in the maze arranged with food box at *f*, one of 7 trained with food box at *b*. In the course of learning the number of entrances made by each animal into the *F* and into the *B* alleys were tabulated (along with other data irrelevant here). Group averages of these entrances trial by trial, are shown graphically in Figure 4; where by use of two kinds of lines the records of both groups (one with food box at *f*, one with it at *b*) are plotted on the same graph, facilitating direct comparison. The ratios between the totals of the two types of entrances are furnished in percentages in Table 1.

It is evident upon inspection of the curves as well as of the percentages, that those animals that learned the maze with their

TABLE 1

Showing percentages of entrances into F- and B-type alleys under two conditions of food box direction

SERIES	PER CENT OF TOTAL ERRORS				NUMBER OF RATS USED
	With food box forward		With food box backward		
	F	B	F	B	
1924	74.4	25.6	47.6	52.4	7 + 7
1925	66.0	34.0	46.5	53.5	10 + 10
1926	64.1	35.9	45.1	54.9	10 + 10
1927	67.6	32.4	59.9	40.1	4 + 4

food box in the "forward" position tended to make more blind alley errors in the "forward" direction than did those animals that learned the same maze with their food box placed in a "backward" position. Moreover, the difference holds in kind between the *F* and the *B* alley entrances by each group taken alone: the group with food at *f* made more entrances into the *F* alleys; those with food at *b* made more into the *B* alleys.

2. A year later and two years later, the same technique happened to be used with two groups of 10 animals in each case. The results, as presented in Figure 4 and Table 1, are seen to verify those of the preceding series.

3. In 1927 the same problem was again returned to; but with a variation in technique. In the preceding series the maze had been

allowed to occupy a fixed position in the experimental room; and it seemed not improbable that the animals' orientation had been established with reference to extra-maze sensory cues—differences in light intensity on different sides of the room, the position of the experimenter, position of living cages from which each animal was carried by a single route to the maze entrance, etc. To check such possible cues as these, and experimentally to set in relief against each other the operation of extra-maze and intra-maze factors, resort was had to the rotation method. The maze as a whole was rotated after every third trial through 180 degrees. The experimenter, who was just visible, rotated his position after every trial through 90° counter-clockwise. In this manner the establishing of any constancy of orientation on the part of the maze animal so far as it was in dependence upon extra-maze cues must inevitably be rendered impossible; whereas to the extent that it was built up with reference to spatial or other factors within the maze itself its establishment might be little or not at all destroyed.

The results of this series also are shown in Figure 4 and Table 1. Here the difference in the relative number of *F* and *B* alley entrances for the two different groups is not nearly so pronounced as in the three preceding series where rotation had not been used. Evidently sensory cues from without the maze had formed at least a part of the source of orientation. On the other hand, when the two groups of animals are considered together, it is seen that there is a preponderance of entrances into alleys turned in the directions of the food boxes, in the ratio of 107.7% (67.6 + 40.1) to 92.3% (32.4 + 59.9). This would seem to indicate some orienting with reference to cues lying wholly within the maze.

A further consideration, however, bears upon the matter. In all four series of experiments with this F-B type of maze the data show that where both groups of each series are combined the F alleys were entered more often than the B alleys. The figures are: 1924 series, 122.0% F, 78.0% B; 1925 series, 112.5% F, 87.5% B; 1926 series, 109.2% F, 90.8% B; 1927 series, 127.5% F, 72.5% B. The explanation for this result is not at once

available. One aspect, however, seems significant: a stronger tendency to enter F alleys both by animals feeding at *f* and by animals feeding at *b* would seem to be a function not entirely (at least) dependent upon the location of food box but one dependent presumably upon the location of the entrance. One way of envisaging the matter is to suppose that (stating it loosely) the animal tends to increase the radius of its exploratory behavior; or (more precisely) the animal tends to make turns that are more consonant with the direction originally established in the entrance alley than to make turns that are of the doubling-back type; or (still more precisely conceived) the animal tends to avoid turns of 180° around obstacles, even when a rounded turn is involved. We cannot at this point choose among these interpretations—or others that may be possible.

III. AN EXPERIMENT WITH A MULTIPLE-T MAZE

Incidental evidence of an interesting kind bearing on the question of some orienting function acting as a contributing factor in maze learning, appeared from an unexpected source.[1] Rats were being trained in two mazes constructed on the multiple-T plan.[2] Figure 5 shows the floor pattern of one of them; and the pattern of the other maze was exactly a left-right reversal of this one throughout. They were built of wood painted black, with 4″ runways between 8″ walls, requiring no covering. Sliding doors were built at five places in each as indicated by dotted lines in the graph.

Ten rats were trained in the maze shown in the figure, called the A maze; 9 completed training in its complementary, called B. Both mazes were rotated 180° before each fifth trial in the learning series, in order to eliminate extra-maze cues as sources of guidance.

Of the various points in the outcome of this investigation, one incidental one is relevant to our general problem. It was found that in the course of learning these mazes the animals tended to

[1] This was a study of maze patterns and their transference being conducted by Miss Ruth Hamill in the spring of 1929. A report of her complete investigation will appear later.

[2] This is the type first described by Stone and Nyswander (1927).

make more entrances into certain blind alleys than into others, and that the two groups of animals tended to show the same differential results on this score. This is shown in Table 2. There we observe that the blind alleys "C" were consistently entered most frequently; and that the others were entered less and less in the order: "E," "A," "B" and "D," "F." Now, it should be noted that the blinds least frequently entered in both mazes—"F," "D," "B"—are all blinds that involve turns definitely the reverse of the food box direction; while of the

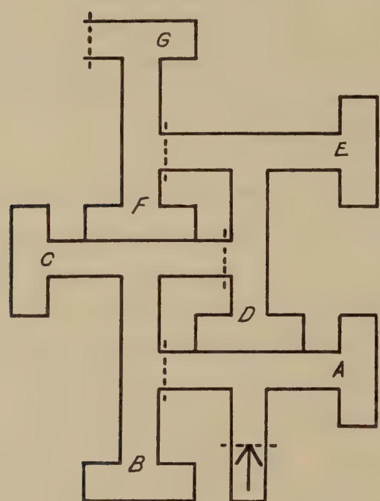


Fig. 5. The Design of the Multiple-T Maze

remaining three alleys the one most frequently entered—"C"—is the one the entrance into which is distinctly more in line with the food box direction. Moreover, this relative preponderance of certain errors over others (in the order given) did not begin to appear until after the first two or three runs.

It would seem a fair conclusion that the animals were guided in their running in some degree by an orienting function which had become established in the course of learning the maze.

In this connection mention should be made of Yoshioka's recent finding, with the use of a simple 2-alternative-pathway

maze, that the white rat shows no sense of direction in an ordinary maze situation, but in an open space orients itself toward the direct route to the goal (1929b). While our results with the F-B alley mazes described in section II above, were ambiguous in their interpretative indication, those just described with the multiple-T maze are less so; and they certainly tend to show that a rat may orient itself while in a maze learning situation.

Confirmatory evidence for the last assertion is offered in an early study by Lashley and Hubbert (1917) and in a recent one by Lashley (1929, p. 137–8). In the former case, white rats being trained in the circular maze were found to run with their heads close to the partitions that lay toward the food compartment and to confine their efforts to climb out to these partitions.

TABLE 2

Showing total number of entrances into the different blind alleys of mazes A and B

	BLIND ALLEYS					
	"A"	"B"	"C"	"D"	"E"	"F"
Maze A	104	52	271	38	176	25
Maze B	158	43	261	53	222	20

In the latter study, after a maze had been learned by rats the wire mesh cover was removed and the entrance was blocked: 5 of the 20 rats climbed up and pursued a direct course across the tops of the partitions to the food box, while of the remainder only 3 wandered about and the others dropped into the first alley and ran their usual route. Lashley concludes that "the most important features of the maze habit are a generalization of direction from the specific turns of the maze and the development of some central organization by which the sense of general direction can be maintained in spite of great variations of posture and of specific direction in running" (1929, p. 138).

THE FORMAL EXPERIMENTS

I. AN EXPERIMENT WITH OPEN-ALLEY MAZE. FIRST SERIES[3]

Our more definite evidences for orientation in white rats were obtained incidentally to another project. We had been interested in learning whether with many alternative paths offered it a rat will tend to (a) follow walls or wall-like barriers or (b) to take more "bee-line" paths or (c) to take intermediate or varying courses—when all such pathways are equal in length if reversals be excluded. But the findings assumed much more significance in terms of the orientation problem.

An open-alley multiple-choice maze design was adopted that would permit travel from entrance to exit *via* many crisscrossing and equal-length alternative pathways, each pathway offering the subject numerous opportunities for false turns. The maze is shown in Figure 6. It was built of unit materials in a take-down form of construction. It was 36 inches square with runways 4 inches wide and partitions 4 inches high. The partitions were made of galvanized iron painted black; the floor was covered with black cork linoleum, and the top consisted of a black wire-mesh. Light was furnished by one 60-watt lamp suspended 8 feet above the center of the maze. The entrance alley was 12 inches long, the exit alley, 8 inches. A noiseless sliding door was placed in both entrance and exit alley at a distance of 4 inches from the threshold of the maze.

A food box was used separate from the maze itself. It was made of wood 8″ x 15″, with walls 4 inches high punched with ventilating holes, a removable metal floor, a wooden cover with handles, and in one end a wire-mesh entrance door $2\frac{1}{2}$″ wide x 3″ high which was so hung by staples as to swing freely inward but not outward.

[3] This work was done with the coöperation of Dr. W. W. Rogers in 1925.

Food was used for the incentive. Bread soaked in milk was placed in small quantity in the food box; and an animal upon entering was allowed to feed for 30 seconds, after which it was removed to a large box where it joined others that had already run the maze and were being allowed to finish their daily meal.

Two groups of rats—an A group of 3 males and 3 females, and later a B group of 4 males and 4 females—about 12 weeks old, were selected from three different litter groups each. For five days previous to the formal runs the rats had practice in pushing open the swinging door of the food box to obtain the daily ration.

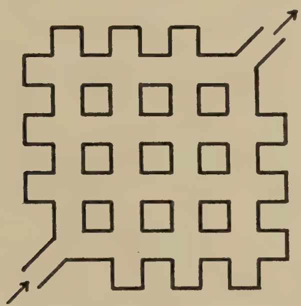


FIG. 6. THE ORIGINAL FORM OF OPEN-ALLEY MAZE USED

Trials in the maze were given once per day (4 P.M.). Each rat in turn was placed in the entrance, and the particular course taken by it was traced by the experimenter upon a printed blank. An error was noted whenever the rat took a direction that involved excess distance in running from entrance to exit: *i.e.*, any runs in the open alleys in the direction of the two sides of the maze that were adjacent to the entrance, or any runs into the pockets on any of the four sides. In this maze there was, as is readily seen, no single 'true' or correct course from entrance to exit: in fact, there were twenty different ways by which the animal could make the run without any false turns involving excess distance, one course being as economical as any of the other nineteen.

TABLE 3

Showing number of errors on successive trials in the open-alley maze shown in Figure 6; and in case of errorless or 1-error runs the corresponding index letter from Figure 7

RATS	TRIALS																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
A Group																											
"01"	16	7	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0	0
			a	*c*	*f*	*o*	*f*	*f*	*f*	*b*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*o*	*g*	*b*		*f*	*f*	*f*	*f*	*f*	*f*
"10"	2	5	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0
			h	*d*	*q*	*f*	*f*	*f*	*f*	*f*	*o*	*a*	*f*	*a*		*a*	*c*	*c*	*p*	*f*	*f*	*f*	*b*	*g*	*c*	*b*	*i*
"11"	16	4	5	3	7	5	0	3	1	0	2	0	4	0	0	0	1	2	0	1	1	1	1	0	1	0	1
							t		*a*	*a*		*a*		*t*	*a*	*t*	*k*		*t*	*a*	*t*	*t*	*t*	*t*	*q*	*q*	*a*
"12"	9	3	5	0	5	5	0	4	1	4	4	2	7	1	3	4	1	1	1	1	1	0	0	1	1	3	2
				a			*a*		*a*					*a*			*a*	*a*	*r*	*a*	*a*	*k*	*a*	*a*	*e*		
"21"	25	3	1	2	1	0	0	1	0	0	3	0	0	0	2	0	0	0	1	0	0	1	1	1	0	1	1
			t		*c*	*o*	*c*	*s*	*c*	*m*		*a*	*s*	*a*		*q*	*d*	*a*	*a*	*s*	*c*	*s*	*c*	*s*	*s*	*k*	*a*
"30"	2	11	1	1	1	0	4	0	0	0	3	0	0	0	1	1	0	2	3	2	0	0	0	0	0	2	0
			q	*a*	*k*	*b*		*c*	*b*	*c*		*d*	*c*	*f*	*p*	*i*	*o*				*e*	*s*	*s*	*s*	*e*		*e*
B Group																											
"01"	6	5	8	1	0	2	2	1	4	2	1	2	0	0	0	1	1										
				a	*b*			*t*			*p*		*f*	*f*	*f*	*b*	*t*										
"02"	7	3	2	4	13	3	0	1	0	5	0	1	0	1	0	2	1										
							a	*t*	*t*		*a*	*t*	*i*	*s*	*k*		*t*										
"11"	1	3	1	8	2	0	1	0	1	0	0	1	0	1	1	1	0										
	t		*t*			*t*	*a*	*e*	*a*	*a*	*a*	*t*	*k*	*k*	*l*	*a*	*a*										
"20"	8	2	8	1	3	3	2	1	2	2	1	0	1	1	1	2	3										
				a				*k*			*a*	*d*	*a*	*t*	*k*												
"21"	0	6	3	8	1	3	1	6	1	15	3	3	0	4	0	0	1										
	t				*a*		*a*		*t*				*b*		*e*	*a*	*o*										
"22"	8	6	1	0	0	1	1	1	4	0	4	0	1	0	1	0	0										
			t	*k*	*a*	*t*	*t*	*t*		*t*		*a*	*j*	*j*	*t*	*t*	*t*										
"03"	8	1	5	1	4	3	2	1	4	1	3	0	3	0	5	3	3										
		a		*a*				*a*		*a*		*a*		*a*													
"30"	25	3	1	2	3	2	2	1	2	0	0	0	5	0	1	1	1										
			t					*j*		*d*	*j*	*e*		*e*	*e*	*s*	*t*										

Group A was given 27 runs, group B, 17 runs.

The striking and important observation made by the experimenter was the following. When first a hungry animal was admitted into this open-alley maze its behavior was of the expected "random" type, terminating eventually in an exit from the maze into the food box; but after a very few trials, it became evident that the reduction in time and distance with repetition of trials, was *not* incidental to the *fixation of a particular course of runs and turns* between entrance and exit. On the contrary, an animal was learning to adjust to the situation by *running in the general direction of the exit, now by one succession of runs and turns and now by another*, so that in a series of trials it followed a variety of different—*but equally economical or errorless—routes* from entrance to exit.

From the graphic records of the individual animals the data was restated quantitatively and qualitatively, and set forth by the following method of tabulation. See Table 3. Opposite the name of each rat is given its record in each of its trials in terms of the number of errors made. In addition, whenever the run made involved no error or only a single error, the run is given a letter corresponding to that used in Figure 7, which shows all twenty types of the possible errorless routes, with index letters. Crosswise inspection of the table shows that there is an irregular reduction of errors in the series of trials; and, more importantly, that when errorless or near-errorless runs were made they varied in type, often even when occurring in immediate succession. Incidentally, one may note that some subjects tended to use more of the round-the-edges type of run ("a" or "t"), others more of the zig-zag-cut-through type ("f" or "o"), while still others showed a frequency of types intermediate between these; but he will also note that in no case (except B-03[4]) were the errorless or near-errorless runs consistently of the same type.

A conclusion of quite first importance is indicated by the foregoing results. When an animal is learning a maze of this

[4] And even in the case of B-03 four of the six errorless or near-errorless runs followed runs that approximated those of very different types.

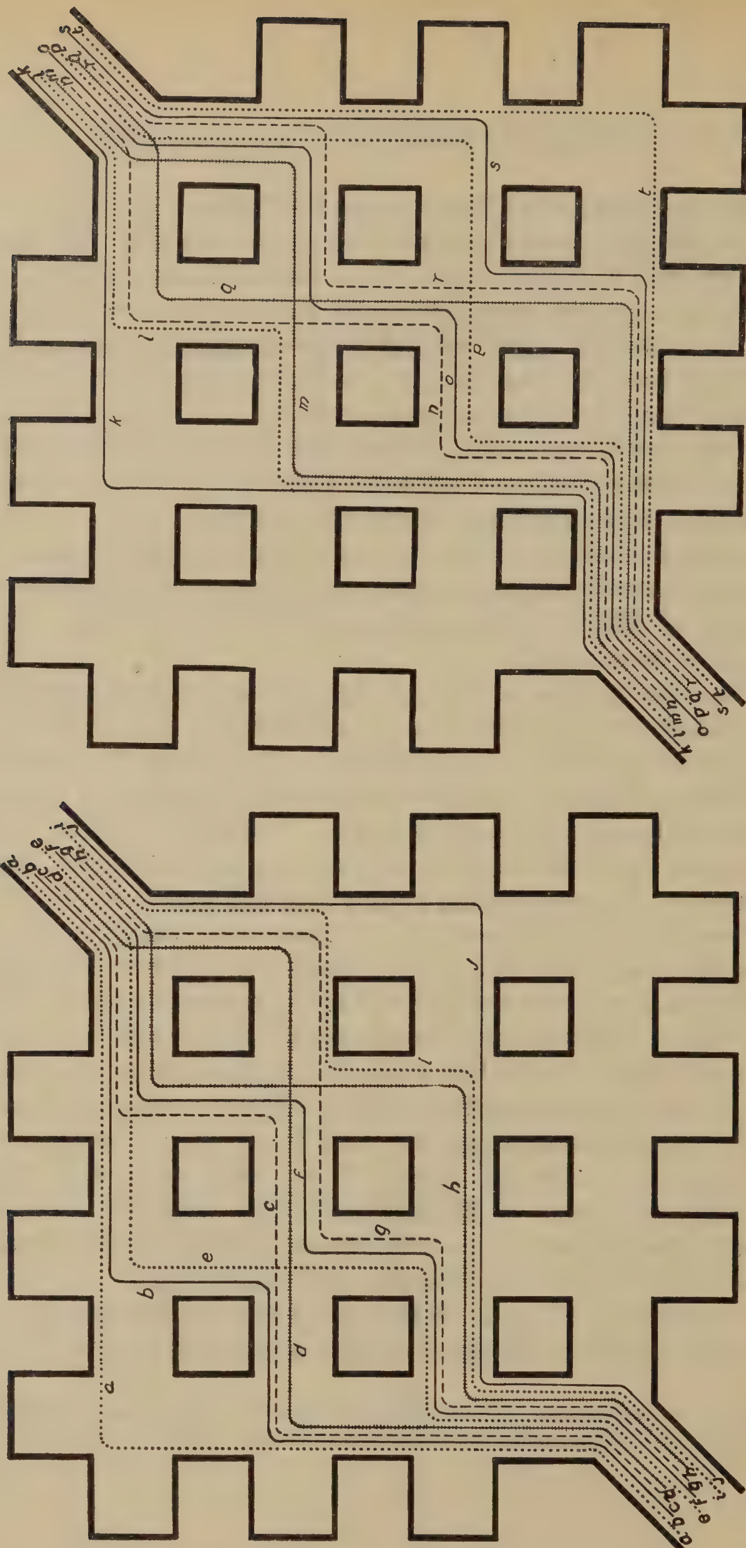


Fig. 7. All the Possible Errorless Routes (Twenty in Number) That Can be Taken in Running from Entrance to Exit of the Maze Shown in Figure 6

open type, with many alternative equal-length pathways, the learning consists in the establishing not of a definite *pattern of specific* turns but of some more *general orientation* function. This general function enables it to pursue new pathways from time to time, the while remaining successfully oriented in the direction of the objective. Instead of learning one pathway-pattern to the goal by the often-stated process of (a) chancing upon a certain way that turned out to be adaptive or successful and then (b) fixating this way by tending to repeat it more and more—our animals *learned to become adjusted in some more general manner, directionally*, which more general adjustment then served as *a steering or influencing factor operative somewhat independently of the purely local stimuli encountered* by the rat and so serving to guide it *even when tracing pathways never before entered.*

The problem as to what this orienting function might be we were not at this time in a position to attempt to solve in any definite way.

Two experimental checks, however, were employed. On the 16th trial with group B, any olfactory stimuli emanating from the food in the food box to serve as guiding cues, were eliminated by removing the food box entirely from the exit. On the 17th trial visual guidance by stimuli from without the maze was eliminated by a 90° rotation counter-clockwise. As is to be seen upon inspection of the records for the 16th and 17th trials in the table, no significant disturbances of the animals' behavior were created by the elimination of either of these possible sources of exteroceptive guidance. However, a more systematic experimental control of such factors was now seen to be clearly demanded.

II. AN EXPERIMENT WITH OPEN-ALLEY MAZE WITH SENSORY CONTROLS[5]

A repetition of the foregoing experimentation but with a program of checks on possible sensory cues, became the next

[5] The work to be described in this section was done with the coöperation of Mr. J. C. Bagwell in 1927.

task. The same maze pattern was employed, and the physical characteristics of the situation were the same with the sole exception that light was cast now by four 60-watt lamps suspended 5 feet above the four corners of the maze. The learning trials were now given twice daily (7 A.M. and 7 P.M., instead of once daily).

The program of controls used in this experiment was as follows. To check *visual* and *auditory* cues from outside the maze—(a) after every 5th trial the maze was rotated 90° in counter-clockwise direction; (b) after every trial the experimenter shifted his position from right of entrance alley to left, or vice versa. To check *visual, olfactory,* and *other cues from within* the maze—after every 10th trial the maze *pattern* was rotated as usual but not the floor, walls and covering, the old entrance and exit being walled up and new entrance and exit made by opening up formerly blank corners: the animals thus being offered a maze identical in pattern and type of materials but differing not only in cardinal direction of the pattern but also in the direction in which the animals were to cross over the linoleum floor and under the wire-mesh cover and in the particular wall-plates they were to pass. Further to check possible *olfactory* cues—(a) at the end of every 20th trial the food box was thoroughly cleansed with a deodorant and replaced in position without food; (b) for the 21st and 41st trials another food box with food was placed alongside the right-hand corner of the maze, and air drawn from the box was driven through the maze sidewise from right to left by a small electric fan; it being expected that if the rats were under guidance by odor they would proceed over toward the side of the maze where the new food box was standing. *Auditory* cues had been further eliminated by the fact that no animal was left in the food box while another was running the maze. Finally, to check *several* possible cues—on the 51st trial, the former exit was walled up and a new exit with food box was opened up at the left-hand corner of the maze; and since the position of the entrance was unchanged (except for the usual rotation and shift of materials following every 10th trial) the relative position of exit to entrance was now radically altered.

TABLE 4

Showing number of errors on successive trials in the open-alley maze shown in Figure 6 under conditions of more rigid sensory controls; and in case of errorless or 1-error runs the corresponding index letter from Figure 7; also notations on the program of sensory controls

TRIALS

RATS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
"01"	19	1 *t*	1 *t*	1 *q*	6	8	6	2	1 *k*	1 *t*	2	0 *a*	0 *a*	0 *a*	3	0 *a*	0 *t*	2	0 *a*	1 *t*
"02"	15	8	1 *t*	0 *t*	4	1 *t*	4	2	3	1 *q*	3	0 *t*	0 *t*	1 *a*	0 *t*	1 *t*	1 *a*	0 *a*	8	0 *p*
"03"	18	3	2	4	2	1 *t*	0 *t*	0 *t*	0 *t*	0 *a*	1 *a*	0 *t*	3	2	0 *t*	0 *t*	0 *t*	9	0 *a*	3
"11"	11	3	1 *t*	2	6	0 *k*	2	0 *a*	1 *t*	6	4	1 *a*	0 *a*	0 *d*	2	2	0 *a*	0 *a*	0 *d*	0 *d*
"13"	3	8	9	2	3	1 *t*	7	4	2	4	2	1 *a*	2	2	1 *t*	1 *t*	1 *t*	2	1 *a*	0 *q*
"20"	10	4	0 *t*	1 *k*	1 *k*	2	3	1 *a*	1 *q*	0 *r*	1 *q*	0 *k*	1 *t*	0 *k*	0 *k*	4	1 *p*	1 *j*	3	1 *a*
"21"	10	2	2	7	8	5	0 *t*	5	3	0 *a*	1 *t*	3	8	0 *a*	0 *a*	4	0 *a*	1 *t*	0 *a*	4
"12"	18	9	9	3	0 *t*	1 *t*	2	4	3	4	2	13	6	2	3	1 *a*	2	2	1 *k*	2
"22"	15	3	3	1 *a*	9	1 *a*	2	1 *t*	5	3	1 *t*	0 *t*	2	0 *t*	0 *a*	0 *a*	1 *a*	1 *t*	1 *a*	0 *t*
"30"	12	6	2	2	1 *t*	7	0 *a*	1 *s*	1 *a*	6	0 *a*	3	1 *a*	0 *a*	2	0 *t*	1 *n*	0 *n*	0 *n*	0 *n*
"32"	18	35	5	2	0 *t*	1 *t*	1 *t*	4	4	6	0 *a*	0 *a*	1 *a*	2	0 *a*	3	1 *t*	1 *t*	0 *a*	0 *a*
experimenter shifted every trial						rotated 90°					rotated 90° change of maze materials					rotated 90°				

RATS	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
"01"	0 *a*	0 *a*	0 *a*	1 *a*	1 *a*	1 *t*	4	1 *a*	2	0 *a*	0 *a*	0 *a*	0 *a*	0 *a*	0 *a*	1 *t*	0 *a*	1 *t*	0 *t*	0 *q*	1 *r*
"02"	0 *a*	1 *t*	5	2	3	20	1 *n*	2	0 *o*	1 *f*	0 *e*	1 *f*	0 *e*	5	0 *e*	2	5	1 *t*	0 *t*	1 *t*	3
"03"	0 *t*	0 *t*	0 *t*	6	1 *a*	3	0 *e*	0 *t*	3	2	0 *t*	1 *b*	0 *d*	1 *t*	0 *t*	0 *t*	6	0 *t*	0 *t*	0 *t*	1 *t*
"11"	0 *a*	1 *j*	1 *t*	0 *a*	1 *a*	0 *d*	1 *g*	0 *s*	1 *n*	1 *s*	1 *c*	0 *s*	1 *e*	1 *f*	1 *p*	1 *t*	0 *t*	0 *d*	1 *t*	1 *q*	0 *q*
"13"	1 *t*	3	3	1 *r*	0 *a*	0 *q*	0 *a*	1 *a*	4	0 *j*	2	0 *t*	1 *t*	0 *q*	3	0 *t*	0 *q*	1 *d*	5	4	0 *a*
"20"	1 *a*	0 *a*	1 *p*	1 *p*	0 *r*	1 *q*	1 *r*	2	1 *t*	0 *t*	3	2	0 *t*	0 *t*	1 *a*	0 *t*	0 *a*	1 *t*	1 *t*	0 *t*	2
"21"	0 *a*	4	0 *t*	0 *t*	1 *t*	2	0 *a*	4	4	0 *a*	0 *t*	1 *t*	0 *a*	1 *a*	1 *t*	1 *t*	5	0 *a*	0 *t*	4	2
"12"	4	4	0 *t*	4	0 *a*	1 *a*	0 *a*	0 *d*	1 *a*	1 *a*	1 *a*	0 *a*	0 *d*	0 *d*	0 *t*	0 *t*	1 *t*	0 *a*	0 *t*	0 *t*	0 *p*
"22"	4	0 *a*	3	0 *t*	0 *a*	5	2	5	2	1 *t*	0 *t*	0 *t*	0 *t*	1 *a*	0 *t*	0 *t*	5	1 *t*	0 *t*	3	6
"30"	0 *k*	0 *a*	0 *a*	0 *n*	0 *n*	0 *n*	0 *a*	1 *t*	0 *k*	1 *b*	1 *a*	0 *b*	1 *a*	0 *o*	0 *o*	1 *n*	1 *a*	0 *t*	3	0 *t*	0 *j*
"32"	0 *a*	1 *a*	1 *j*	0 *j*	0 *d*	1 *t*	2	0 *t*	1 *t*	3	0 *t*	2	1 *t*	0 *a*	0 *t*	1 *t*	0 *j*	0 *a*	1 *t*	0 *q*	0 *q*
	rotated 90° change of maze materials deodorant food box at side					rotated 90°					rotated 90° change of maze materials					rotated 90°					rotated 90° change of maze materials deodorant food box at side

RATS	42	43	44	45	46	47	48	49	50	51
"01"	0 *a*	0 *t*	0 *t*	0 *a*	4	0 *t*	0 *a*	1 *t*	5	*t*
"02"	0 *t*	1 *w*	0 *t*	0 *o*	0 *a*	1 *f*	0 *r*	0 *r*	1 *t*	*a*
"03"	0 *t*	3	3	4	3	0 *t*	2	1 *t*	1 *e*	*t*
"11"	0 *h*	1 *e*	1 *e*	0 *e*	2	0 *a*	0 *t*	0 *t*	0 *t*	*t*
"13"	3	1 *a*	2	0 *g*	1 *l*	1 *l*	1 *o*	0 *p*	0 *o*	*f*
"20"	0 *a*	0 *a*	1 *c*	0 *q*	0 *t*	0 *q*	0 *t*	0 *t*	0 *t*	*a*
"21"	1 *t*	1 *b*	4	2	1 *t*	4	1 *t*	2	0 *a*	*a*
"12"	0 *q*	5	1 *k*	1 *o*	0 *b*	0 *o*	0 *h*	1 *i*	1 *h*	*s*
"22"	1 *a*	0 *k*	0 *d*	0 *t*	0 *a*	2	0 *t*	1 *a*	0 *a*	*t*
"30"	0 *t*	4	0 *t*	2	3	2	1 *q*	2	0 *k*	*a*
"32"	1 *a*	0 *q*	2	0 *q*	1 *t*	0 *a*	0 *t*	2	2	*k*
					rotated 90°					rotated 90° change of maze materials shift of exit to left corner

The records of runs in this experiment are essentially like those of the preceding one, as described in section I. The evidences for the presence of some orientation factor in the manner and directions of the animals' running remain much what had been found earlier under conditions of less rigid sensory controls.

Again we make a tabular analysis of the records, in Table 4, after the same fashion as in Table 3, showing for each rat the number of errors per trial, and on those trials when one or no error was made showing the type of run by an index letter corresponding to that used in Figure 7. A letter was also used to characterize the 51st run, as nearly as could be done, though a count of errors on this run would be ambiguous. Inspection of this table brings to light two things of some interest.

For one, it is to be noted that errorless and one-error runs became extremely frequent but at the same time they appeared in a great variety, even when in immediate succession. Particularly worth noting are the trials numbered 22 to 42, inclusive, of animal "11:" in these 21 runs 13 different routes were included with only 3 cases of an immediate repetition. For the eleven animals, the number of different routes taken by each in errorless or one-error runs was as follows, in order: 6, 9, 5, 14, 11, 8, 3, 9, 4, 9, 5.

For another thing, it is to be noted that errors were not increased in consequence of any of the special sensory controls with which the experimental procedure was modified. A survey of the error scores without knowledge of when the sensory checks were applied, would give one no basis at all for intelligently surmising the latter. In fine, it is clear that whatever be the orientation function brought to light by results referred to in the preceding paragraph, such function is not dependent upon any stimulus sources which those controls were set to eliminate. These include: visual, auditory, or olfactory stimulations from within or from without the maze. (The one incompletely checked source was that of possible minimal cues from the experimenter—but not from experimenter's position. Such minimal stimuli have never been found effective with the rat, and might logically be neglected; but they were experimentally eliminated in a later

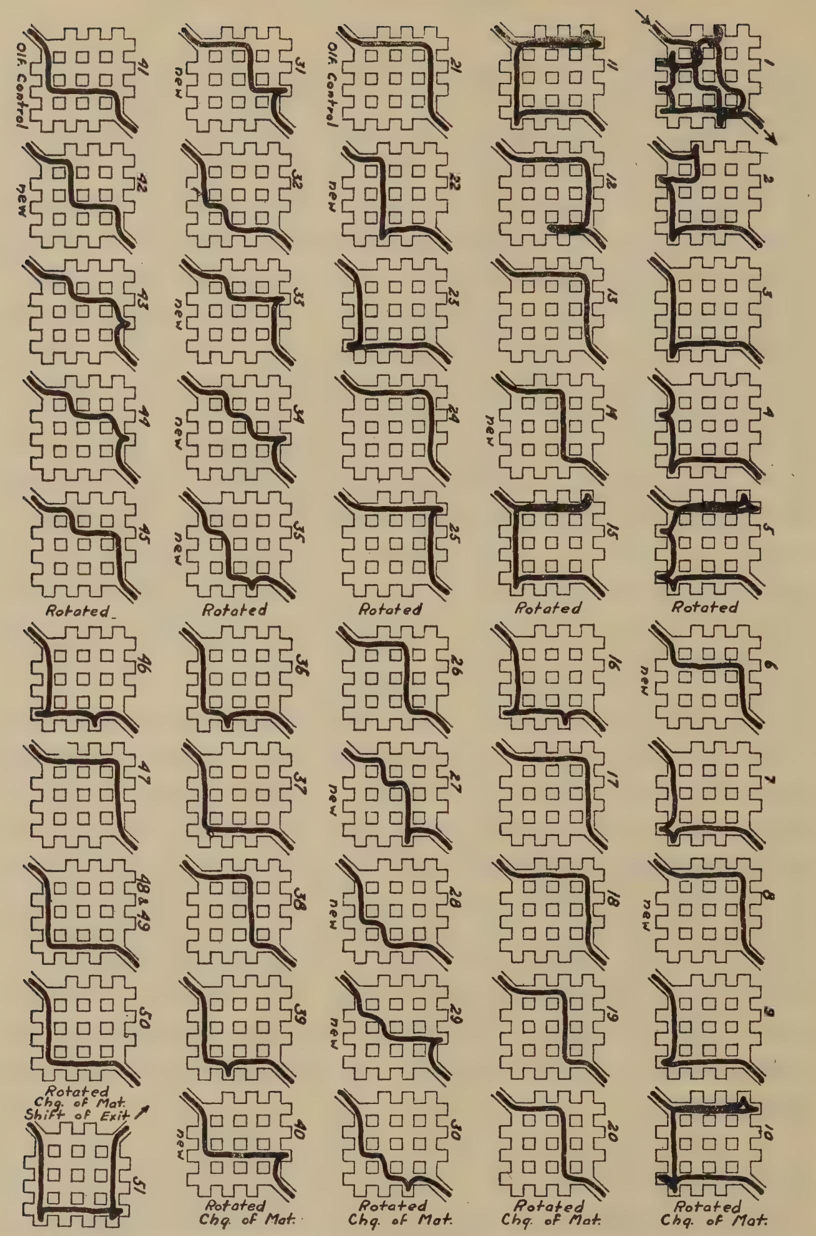
experiment, to be described in section V.) Tactual cues are out of the question by reason of the very variety of the errorless runs, some of them being through passages not previously used; for this type of cue is dependent upon quite local stimulation and hence could not be of guidance value in new passages. Finally, kinesthetic patterns as sources of guidance are equally out of the question because of the variety in the errorless runs. (This is not to deny some other rôle of kinesthesis in the orienting process, but only its organization by habit into a certain fixed pattern.)

A more concrete presentation of our results is offered in Figure 8, which shows small-scale copies of the actual courses taken by rats in their successive trials. Due to limitations of space we show only those for animals "11" and "30." An additional notation introduced is the use of the word "new," which appears under the records of those errorless or single-error runs which involved routes or segments of routes that had not been previously taken in any runs whatever, either errorless or erratic, and hence were essentially new routes. Their significance is obviously enough in line with the above analyses.

In the light of these facts it became clear that the orienting of the rat in a maze of our type could not be a function operating under the actual directing guidance of present stimuli from the food box nor from any landmarks near it. The function is one that is learned, that becomes established after a few experiences; but it is certainly not learned as an ordinary habitual response to exteroceptive stimuli from the objective, as habits are usually conceived. We failed to find the source of guidance in the maze environment as such. Could it, then, be a matter of how the animal was introduced into the maze? To approach this experimentally, a further variant on our technique was next adopted.

III. AN EXPERIMENT WITH CHANGEABLE ENTRANCE DIRECTION

After the definite negative outcome of the preceding experiments so far as exteroceptive guidance was concerned, our problem took further shape in the query: is the orientation func-



Olf. Control
new
Rotated
Rotated Chg. of Mat.
Rotated Chg. of Mat. Shift of Exit

FIG. 8A

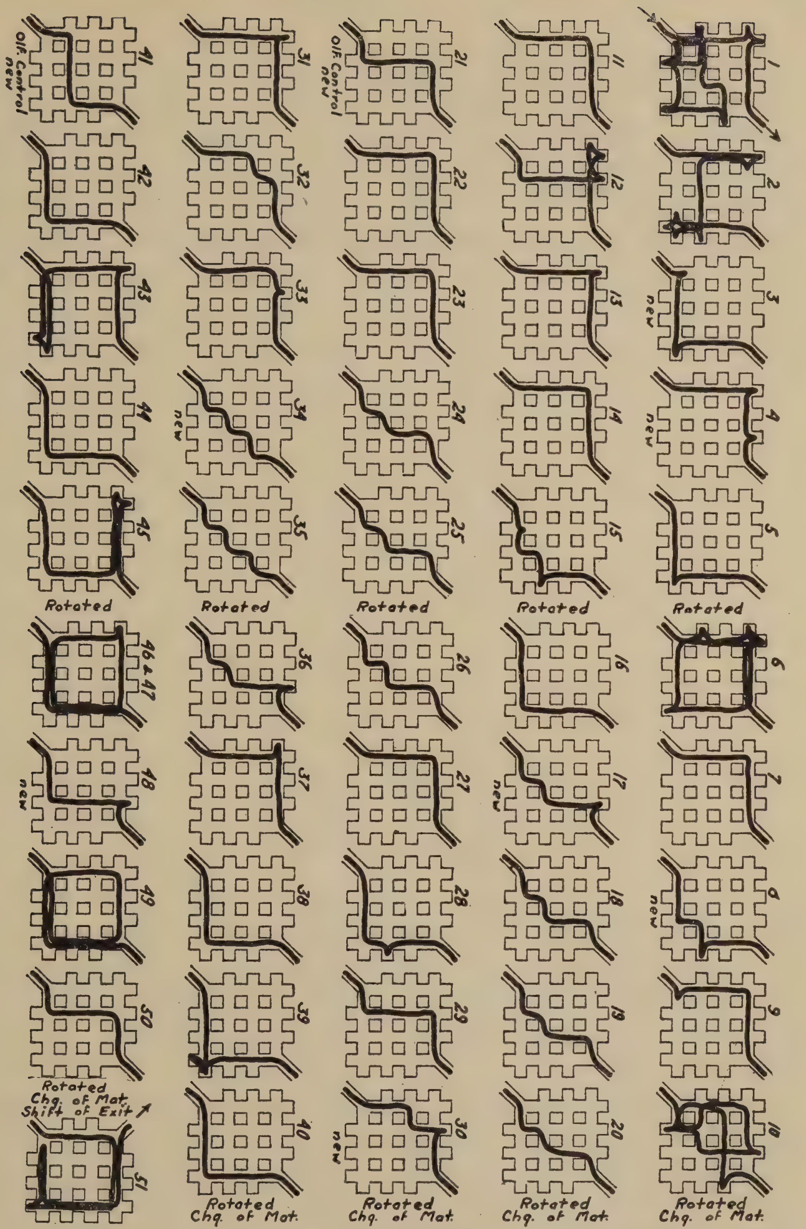


FIG. 8B

FIG. 8. FACSIMILE TRACINGS OF ROUTES TAKEN ON SUCCESSIVE TRIALS IN THE MAZE SHOWN IN FIGURE 6, BY TWO TYPICAL ANIMALS

a, record for animal 11; *b*, record for animal 30. For notations see text.

tion dependent upon the particular manner in which the animal is introduced into the maze? May it not be that when the animal first enters, some form of set or posturing may be established by the gross orientation in the entrance alley, and that this posture may set up kinesthetic and organic afferent processes that serve as the sensory cues in the maintaining of orientation?

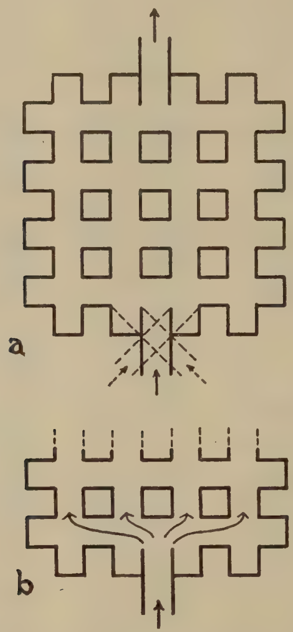


Fig. 9. Maze Shown in Figure 6 Rearranged to Place the Entrance on One Side

a, the original entrance shown in solid lines; altered directions of entrance shown in broken lines. *b*, arrows show the four types of beginnings of runs made in maze shown in *a* (alterations of the entrance not shown in *b*).

To attack this phase of the problem experimentally the maze design previously used was altered somewhat to permit of a deflection of the entrance alley to right or left. Figure 9 (a) shows the maze employed, dotted lines being used to indicate changed positions of the entrance alley in the late trials.

Ten animals were given fifty runs each in this maze, with entrance in the fixed position pointing toward the center of the

maze. Their behavior throughout the series was much the same as that of the animals in the preceding experiments: they often followed widely different routes from trial to trial, some of these routes being run for the first time and in errorless manner. Further details on this part would be repetitious here. After the 50th run, however, the experimenters altered the angle at which the entrance passageway (12″ long) was articulated with the maze. For the 51st and 52nd trials it was turned 45° to the right, thus pointing markedly into the left-hand half of the maze; for the 53rd trial it was turned 45° to the left of the original position and pointing into the right-hand half of the maze.

TABLE 5

Showing types of run beginnings made when the entrance passageway was turned left or right

	TRIAL		
	51st	52nd	53rd
Direction of entrance	L	L	R
Number animals that travelled:			
To left 1 block	6	6	—
To left 2 blocks	4	3	—
To right 1 block	—	1	7
To right 2 blocks	—	—	3

Figure 9 (b) shows the four types of beginnings of runs on these three trials; and Table 5 shows the frequency of each for the whole group under the different conditions. Briefly, in all but 1 of the 30 individual trials, the animal followed for shorter or longer distance the direction of his initial orientation as determined by the entrance passageway. The complete routes followed by many individuals were, however, hard to interpret. After entering the maze to left or to right, they would run directly down the longitudinal pathway or aisle they were in, and, upon reaching the far wall, they would turn, possibly under visual guidance, into the exit to food box. The aisle-like straight passages from near the entrance to near the exit did not offer enough thwartings. In a word, the maze was not such as really

to test the orientation function, beyond the moment of first entrance.

It seemed then next in order to try overcoming any possible disadvantage of entrance from the side of the maze with any possible initial mechanical guidance that might have, by introducing the animal directly into the center of the maze.

IV. AN EXPERIMENT WITH SPONTANEOUSLY DETERMINED ENTRANCE DIRECTION[6]

In order to see whether the rat tends to follow its original orientation, even when the latter is not specifically determined mechanically by the external conditions, another type of open-alley maze was set up, with a novel method of introducing the animal. The apparatus was built of the same kinds of materials as those used in the preceding experiments at the North Carolina laboratory. The innovation used was the arrangement of an entrance at the center of the maze, and in a direction to be dependent upon the animal alone. The ground plans are shown in Figure 10 (a) and (b). In (a) is shown the plan used for the first 40 trials; in (b) that adopted for 20 remaining trials. All lines represent 4″ walls, excepting the circle at the center. Here a circular hole had been cut in the maze; and a cylinder of $\frac{1}{4}$″ wire-mesh reached from the maze floor at the cylinder's brim down 12″ to a movable basket on a table below. For a trial, an animal was carried in the basket to the point on the table immediately below the cylinder. It promptly started climbing up the inside of the cylinder, sometimes vertically, sometimes obliquely; and upon reaching the upper end entered the maze by climbing over the brim. In doing so, it was, of course, always oriented in some direction.

The program of sensory controls followed in the preceding experiment was again closely adhered to in this one.

We shall want to ask as a preliminary question—whether this initial orientation was in a constant direction on successive runs

[6] The experimental part of this section was performed by Mr. J. C. Bagwell (in correspondence with the writer) while at the University of Texas laboratory. For the analysis and interpretation the present writer is responsible.

by the same animal. A negative answer is clearly indicated by the listing of the successive directions of initial orientation for each of the animals. For the sake of convenience (somewhat as is done in describing bridge hands), the names of the cardinal directions are arbitrarily assigned to the four corners of the maze, n (north) being assigned to the exit corner where the food box had been placed. (The reader will not confuse this arbitrary mode of designating parts of the maze with the actual cardinal directions, especially as the maze was rotated after

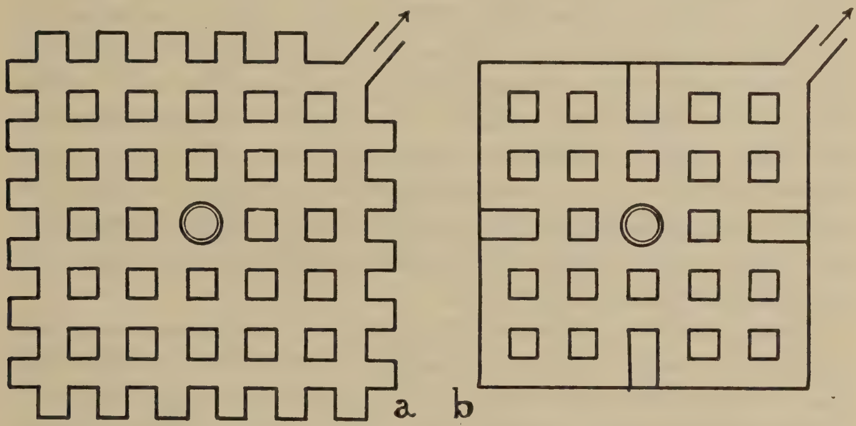


FIG. 10. TWO CENTER-ENTRANCE MAZES

Entrance is effected by animal's climbing up through circular hole indicated by double circles in center of each figure. *a*, as used for first 40 trials; *b*, as used for remaining 20 trials.

every five trials.) The successive orientations were as follows for three of the animals (only space limitations forbid showing for all nine).

"00"—n, sw, nw, nw, w, sw, sw, sw, w, sw, s, sw, sw, w, n, w, s, w, ne, nw, nw, s, ne, nw, n, se, n, ne, e, n, w, n, nw, sw, n, nw, w, n, n, n, n, e, n, sw, sw, n, n, sw, sw, w, w, w, s, sw, sw, w, w, w, w, w.

"01"—nw, n, n, n, n, nw, nw, nw, nw, nw, nw, n, nw, n, n, nw, nw, w, w, w, n, nw, ne, ne, ne, n, n, ne, ne, ne, e, e, n, e, n, n, ne, ne, ne, n, ne, w, n, e, ne, sw, w, sw, w, n, w, s, w, sw, n, n, n, w, n, w.

"21"—s, w, w, e, n, w, w, s, w, w, s, w, w, w, w, sw, s, w, s, s, s, w, w, w, w, w, s, w, s, s, s, s, w, w, w, w, w, w, w, w, w, w, w, w, w, w, w, w, w, w, s, s, s, s, w, w, w, w, w, w.

Certainly there was not a constancy of initial orientation on the part of any animal. Continuities in short series point to the fact that the animals when being placed below the wire-mesh cylinder were faced the same way several times in succession, or else formed temporary habits of climbing up certain sides of the cylinder. But there was no final learning of the most effective side to climb; for there is in no case a definite establishment of a habit of going up on the *n* side.

An important question is: Did the animals tend to follow the initial head orientation, regardless of which way it was directed? Of the *n* initial orientations, 67% were followed completely over to the corresponding side of the maze, and 14% were followed half way over. Corresponding figures for the other initial orientations are: *e* orientations, 73% and 15%; *s* orientations, 69% and 19%; *w* orientations, 58% and 16%. The fairly close correspondence of the percentages for orientations in the four different directions shows conclusively that there was no stimulus-factor in the maze tending to direct the animal out of whatever general direction it had set out in.

Put another way, the rat did not learn the maze as a problem capable of one particular solution, a particular route to the food box. It learned only to run vigorously and variously under the conditions of internal motivation (hunger drive) and of external thwartings (numerous walls and no landmarks). That landmarks were but poorly if at all established, is shown by the fact that even when the animals followed an initial orientation *n* all the way to the wall and within from 4 to 16 inches of the exit, in 25.5% of the cases they did not then proceed to the exit but ran elsewhere about the maze.

V. A CONCLUDING EXPERIMENT

To make the exclusion of all exteroceptive cues from our problem absolutely complete it remained to introduce one further refinement of technique—the elimination of the experimenter from the environment of the rat.

It has long been recognized that the presence of the experimenter operates to furnish cues to certain animals in certain

uncontrolled experimental situations. Johnson (1913) was one of those to demonstrate this fact clearly, by contrasting the data obtained when he was in the same room with and in a different room from the dogs he had in training. It has been a notoriously significant factor in the performance of so-called thinking horses and dogs. The cues furnished by the experimenter in such cases are in the form of obscure stimuli resulting from minimal, unintentional movements, changes in breathing, etc., evoked in him when he observes his subject-animal succeeding or failing. Some animals are so sensitive to the slightest changes of attitude on the part of men with whom they are familiar that they are capable of learning to respond to those changes as guiding cues in their own performance. This guidance by minimal stimuli from observers is essentially the same as the "mind reading" capacity of human seers and clairvoyants. Now, the operation of such cues has not ever—so far as the present writer is aware—been demonstrated in the white rat; it being one of those animals, like the cat and the cow, that show little of that delicacy of inter-stimulation by attitudes, tones and gestures, with their human keepers; and much maze work with the rat has proceeded without complete absenting of the human experimenter.

Accordingly, in our preceding investigations we had not eliminated the experimenter completely. His position had been systematically shifted, so that the distant sight of him could have no "landmark" or directional value. Minimal cues, however, were still a theoretical, if only remotely probable, possibility; and their complete elimination seemed technically desirable. A final experiment was organized with this in mind, as well as to check still once more the findings in the preceding investigations.

The elimination of the experimenter from the maze situation has usually been accomplished by either of three means. Perhaps the most common is by use of a screen used in something of the manner sometimes employed in the police station "third degree" situation: a brilliantly lighted subject if surrounded with the proper cloth fabric remains quite visible to an observer on the dark exterior but cannot himself see the observer. We had originally planned a heavy cheesecloth to be hung smoothly on

all sides of the maze and lighted on the inner surface only. But however completely this device might shut off visual minimal stimuli it furnished no guarantee against the transmission of auditory ones. A second method of eliminating the experimenter is by the peek-hole device, in which he stands back of a more or less substantial partition, as of fiber-board or wood, and observes the animal's performance with an eye placed to a hole cut through. This arrangement appeared to have the same defect as the preceding, unless an entirely separate room were used for the observer. A third method adequately cutting off all visual and auditory stimuli is the peek-hole-in-ceiling: experimenter making his observations while in a supine position on the floor above. Besides the necessity of having a suitable upper floor arranged, there is a disadvantage in the necessity of there being always two experimenters, one to handle the animals and manipulate the apparatus, the other to do the recording. And in any case, it is the writer's experience that observing through a peek-hole and making pencilled records simultaneously is a very inconvenient—and to that degree inaccurate—procedure. We gave up all of the three methods mentioned in favor of a very different one.

We adopted the use of a maze cover of opaque "Synite" glass, one side of which was heavily pebbled, so that objects within two or three inches of one side could be seen more or less distinctly from the other side, but objects a foot or more away were rendered quite invisible. A white rat travelling through a black maze built of only four-inch walls covered with this glass, remains visible enough to an observer at a reasonable distance; while on the other hand, the observer is absolutely invisible to the animal, and even the rays from overhead illuminating bulbs are so diffused in transmission that they produce no wall-shadows. A further advantage of the glass cover is the total interference with transmission of any air sound waves such as might be produced by an experimenter's minimal movements. A possible disadvantage lying in the fact that the glass cover forms an air enclosure with the maze and so is likely to produce stale, body-heated, or odoriferous air, was considered negligible in our case, in view of

the limited dimensions of our maze and the very short time any animal remained in it (never so long as a half-minute).

The maze design used was at the beginning precisely the same as that shown in Figure 6, with minor changes introduced in later trials, as will be described. 16 rats were used.

Thirty-five trials were run, two per day. Through the first sixteen runs, during which the original floor design was retained, the behavior of the animals was of the same character as that reported in sections I and II above: widely varying but equally economical and adaptive routes were used, often for the first time. Among these varying routes the follow-the-wall type (cf. Figure 7, *a* and *t*) had always appeared in higher frequency than the others, with many individuals; and an attempt was made on the 17th to 20th trials to check this preponderance by an alteration in the side walls. This proved ineffectual, and on the 21st trial we returned to the original design but added stops just beyond the right and left corners and invisible from the entrance. In addition, the two blind corners of the maze were extended into diagonally placed alleys closed up at 4 inches depth, thus becoming similar in appearance to the entrance and exit alleys. Success attended these efforts.

Maze rotations of 180° were made after the 8th, 18th, 26th, 33rd, and 34th trials. After the 20th and 26th trials a change of maze materials was secured by rotating them 90° independently of the absolute places and direction of entrance and exit alleys, this through opening up the formerly blind corners and closing up the former entrance and exit. The last two trials of the whole series were set as special tests of the orientation function. On the 34th, in addition to the rotation, the exit alley which had always been opposite the entrance was now closed, and the formerly blind right-hand corner alley was opened up to lead to the food box. On the 35th, the maze floor and materials were not rotated, but the absolute direction of entrance and exit were rotated 180°—by closing up and opening up the proper alleys.

A tabular analysis of the records turned out to be essentially similar to those in Tables 3 and 4, and hardly deserve additional space. In any case, the results are more concretely grasped

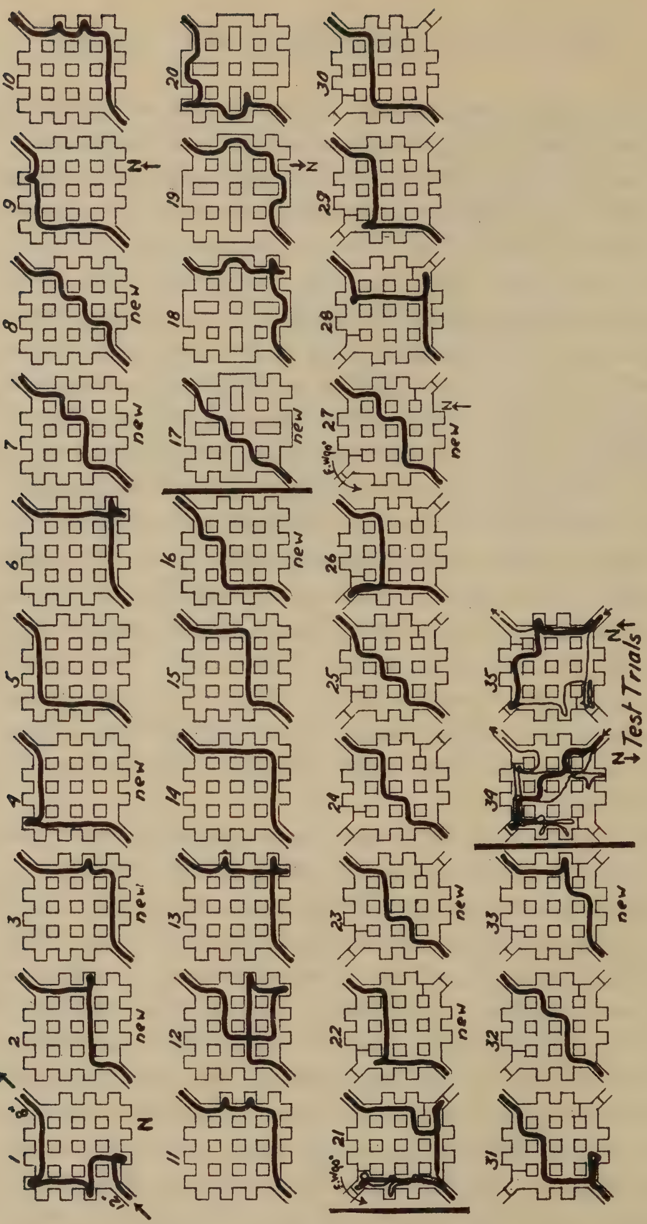


FIG. 11A

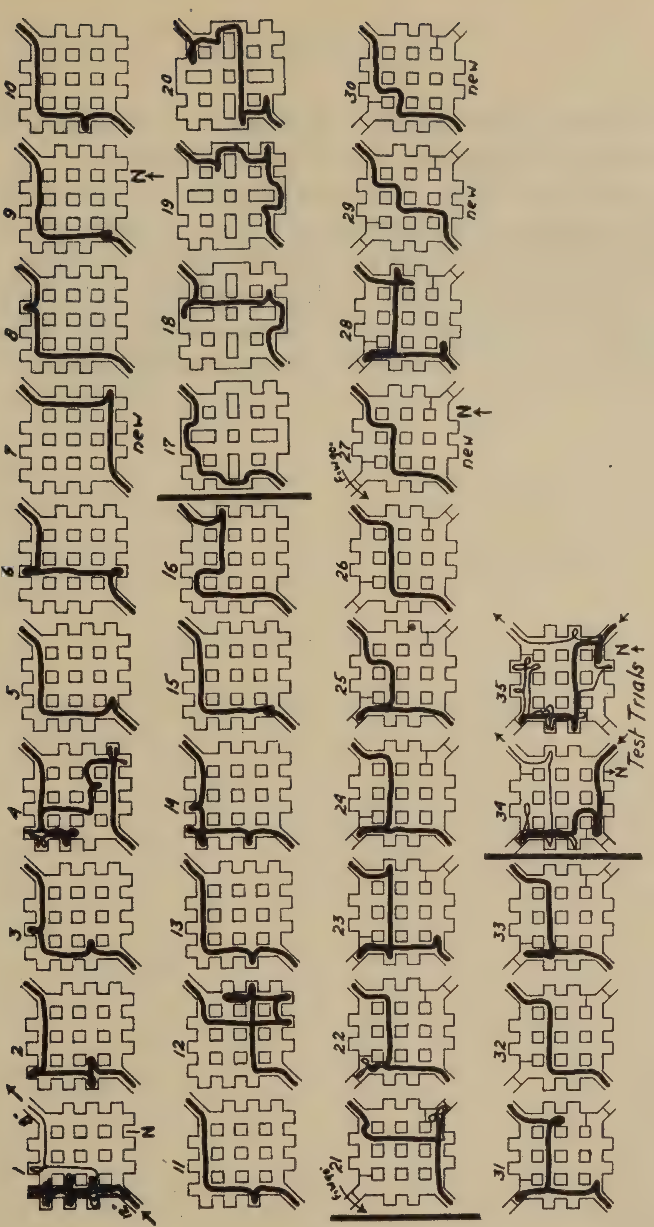


Fig. 11b

Fig. 11. Facsimile Tracings of Routes Taken on Successive Trials by Two Typical Animals

a, record for animal L-2; *b*, record for animal R-6. The same maze design as shown in figure 6 was at first adopted, but alterations in the design were later introduced. For these points and others referred to by notations see text.

from a graphic presentation. In Figure 11 are shown the complete series of runs made by two typical animals.

In general, we have a final confirmation of the results of the several preceding investigations. The animal pursues new pathways while remaining successfully oriented toward its goal. And in the final test trials, the 34th and 35th, the rat's behavior demonstrates conclusively that the orientation is a function of, or is determined by, its manner of first entering the maze.

A SEARCH FOR INTERPRETATIVE CONCEPTS

The behavior of our rats as described is of a character that is so at variance with the usual laboratory findings, and so defies the traditional manner of describing animal learning, that a special attempt to explain or interpret the results is clearly demanded now. In pursuance thereof let us canvass the field of recent and contemporary research, looking into any lines of investigation that appear relevant. We may not expect to find in any of them a complete envisagement of animal learning; yet we may gather up here and there suggestions having contributory value.

I. THEORIES OF HOMING

A familiar answer advanced for the phenomenon of animals' returning from a distance has been the "homing instinct." But this theory, obviously enough, is no more than a confession of ignorance, until the instinct in question is given more detailed description. And in the latter case we are face to face with questions that should be raised in any event: namely, what are the receptive channels involved; and what are the adjusting mechanisms?

1. The exteroceptive recognition of specific landmarks. On this much-employed conception it is held that a homing animal is guided by the recognizing of familiar signs in the environment with which it had become acquainted on its earlier outward-bound excursion. As it moved centrifugally away from its nest, it was receiving stimulation from the trees, houses, bodies of water, floating odors, etc., etc., it passed on its way, affecting the various exteroceptors of sight, hearing, smell, and perhaps touch. The stimulations were sufficient to make some impression on the neuro-motor system; and, on the occasion of the animal's starting to return (due to time of day, to release from captivity, to its being pollen-laden, etc.), it shows a greater

tendency to follow the familiar than the unfamiliar signs or stimuli it now encounters. Thus by the positive tendency toward the familiar stimuli and negative tendency toward the unfamiliar the animal practically retraces its steps to its home.

Some observations have appeared to bear out this theory. One is the so-called "locality survey" reported by the Peckhams, Cornetz, Santschi, and others, for certain ants, bees and wasps. On leaving the nest for the first time the insect appears to make a pretty thorough examination of the immediate neighborhood, flying or running about the hive in imperfect circles of greater and greater radius, at length going off at a tangent on its exploration for food. Much the same has been asserted for certain birds.

Again, many investigators report that changing the appearance of some of the surroundings of the hive or nest is sufficient to confuse the animal completely, rendering it incapable of locating the home.

Now, whatever the advantages or disadvantages of the general theory of orientation through exteroceptive recognitions or familiarities, it is useless as an explanatory principle in the present experiment. The great frequency with which a rat did not follow the same pathway toward the food box in successive errorless or nearly errorless runs, many times taking an entirely new pathway without mistakes, should indicate that the particular sights or other exteroceptive cues to be found in the particular twists and turns of the runways could not be the controlling nor even an important type of stimulation so far as the general orientation is concerned.

2. Guidance by a constant exteroceptive cue. The feat of Alaskan dog teams in keeping straight on to their goal in spite of whirling sleet and darkness over trails long covered with snow has been dramatically presented in newspaper accounts recently. Several attempts at explanation have been made; the most intelligent one, to the writer, being that the constancy of direction maintained by the winds of Alaska was a sufficiently constant cue to keep the animals oriented throughout a long run. Similarly, it is likely that the migrating or the homing bird may operate with

such distant and constant cues as a mountain range ahead, an ocean shore line over on the left, or a river bed below.

In most maze experiments it is conceivable that the animals being studied may become oriented toward the exit or food box by some constant exteroceptive stimulation. An odor emanating from the food may in some cases be present in the maze alleys, although the importance of this has been discounted by most workers, due not only to the fact that the animal shows under any circumstances poor localizing ability for odors but also to experimental variation and elimination of smells in the maze.

More important are the presence of constant stimuli coming in a constant direction from beyond the whole maze. The sounds of animals in a distant nest near a side wall, the direction of light from a single window or from poorly distributed lamps, the sight of a pillar or post, or the sight (and perhaps sounds) from an experimenter who always takes up the same position—these are but a few of the possibilities of stimulation coming from a constant direction operating in a more or less minimal degree.

In the present experiments such factors were completely checked by methods that do not need another repetition of statement here. And it is a matter of assurance that the rats in threading their ways through our maze almost infallibly toward the exit door were not guided by any exteroceptive stimulation of constant nature coming from without the maze.

3. Guidance by some constant intra-organic cue. In the experimental situation of our white rats, we have been unable to locate any sensory stimuli of extra-organic character serving as external guidance for the animal in its maintaining of orientation. It follows that the sensory part of such function must be intra-organic. It is at least imaginable that an animal might carry about with it some direction-indicator that would serve as an orienting device with reference to the cardinal directions, in a way analogous to the function of an electric compass.

Several naturalists, including Bethe and Fabre, have postulated a special direction-sense; and it has been more explicitly described by Thauziès (1909) and others as a "magnetic sense." Arguments in favor of such a conception have, however, not been

convincing, sometimes being advanced to cover types of behavior that have had fairly satisfactory unravelling at the hands of other workers, and at other times reading like an accumulation of conjectures. And since there are no independent lines of evidence indicating the existence of such receptors, it would be gratuitous to assume them. Their postulation may be taken as a symptom or expression of no knowledge on the subject.

Finally, whatever be the merits or demerits of this line of theory, the capacity in question—that of being sensitive to and reacting to a cardinal direction—would be really irrelevant to our problem. Rotations of our maze, whether at regular or irregular intervals, produced no disturbance in the animals' behavior.

4. Orientation by changing intra-organic cues. After being forced to reject for our purposes here any homing theory based upon guidance by exteroceptive cues or by any intra-organic cue of an absolute and unchanging nature, we are logically left but one general alternative: some interpretation in terms of intra-organic cues that are variable in character. It seems possible to conceive of the operation of such cues in the rat's behavior if we grant their effectiveness to vary with varying positions of the animal in its runs. Two points are clear. Since the animal's orientation is a relationship to external spatial conditions, the function must, at least at the beginning of a run, be determined by some extra-organic factor. On the other hand, since the animal is capable of taking a variety of routes to its destination, the orientation function must be of a sort that, once set up, can operate in a degree independently of particular exteroceptive cues from particular details of the maze.

So far as the present writer is aware no theory of homing has been formulated that has as its essence the operation of intra-organic stimuli variable and changing in nature. We are forced, consequently, to convass other modes of investigating animal reactions to spatial characters of their environment.

II. LEARNING A SPECIFIC ROUTE TO A GOAL

1. The traditional maze problem. Quite the greatest number of experimental investigations in animal behavior have been

devoted entirely or in part to maze learning. Since the early work of Small, Kinnaman, Yerkes, and Porter, maze technique has undergone great refinement, and has been modified for suitable approach to many different specific problems in animal and human learning and efficiency. The conception of the maze habit conventionally held has been that it consists of a series of more or less discrete stimulus-response units, the several units being gradually learned and fixated more or less at the same time, yet learned not simply individually but as members of an integrated whole.

In an early investigation Watson (1907) demonstrated by operative methods that the kinesthetic (and organic) sensitivity is the only modality absolutely essential to the formation of the maze habit; but Vincent (1915) and, lately, Dennis (1929) have demonstrated that conditions can be so arranged that other modalities, such as visual, olfactory, and contact, become learned as essential guiding cues. Nor is the environmental sensory field limited to the maze. Porter (1906), Carr (1917), Watson (1907), Hunter (1911), and Sadovinkova (1923), among others, have demonstrated disturbing effects upon maze learning by white rats and by birds when conditions in the extra-maze environment were altered, as by rotation of the maze in the experimental room. (Gengerelli (1928) failed to produce disturbance by rotations in the hooded rat; and some unpublished results in our own laboratory are in agreement with his.) It follows, then, that the maze habit becomes established as a system of responses to a veritable complex of stimuli of different degrees of specificity as to their locality.

A point of quite fundamental significance for us here is that the maze problem as it has heretofore always been set has consisted of a task in learning to follow without false turns a single, definite, specific route from the point of release to the final objective. It has been considered simply as the formation of a serial habit composed of reflex-like acts hitched together end-to-end. Whether (A) this hitching together has been thought sufficiently explained in terms of kinesthetic afferent impulses joining each component act to the next, or (B) the

participation of specific local visual and other exteroceptive cues have been recognized in the determination of the action pattern; or whether (C) a multiplicity of stimuli both from within and from without the maze have been accorded their composite rôle in the guidance of the behavior—in any case, on the motor side the performance demanded of the animal has been the tracing of a single specific pathway from entrance to exit.

Apparent exceptions are found in those investigations in which the animal is presented with a few alternative pathways—as a longer and a shorter; but in such cases the problem becomes simply that of which specific route the animal will come to fixate eventually.

Now, it is obvious that the conventional maze problem, forcing the animal to learn a single, specific route, is quite a different matter from our open-alley apparatus in which twenty different equal-length routes were open. And it is readily to be seen that the basis of explanation invoked in the case of the ordinary maze performance is wholly inadequate to our problem. So far as it has been stated in terms of a particular sequence of proprioceptive stimuli (A, above) or of specific local cues furnishing recognizable landmarks (B), it is totally irrelevant to the type of variable behavior displayed by our rats; and so far as it has depended upon the operation of constant cues from within or without the maze (C), its value for us has been rendered nil by our program of sensory controls in which all constant stimuli have been eliminated.

2. Newer conceptions of the maze problem. Latter day attempts have been made to envisage the process of maze learning in other than the conventional way just described.

Yoshioka (1929a), after training rats in two different pathways of equal length but different pattern, concludes that the simple S-R formula is inadequate to explain maze learning, and that the latter really consists of two tasks: first, to learn that a maze is something to be run through for a reward, and second, to acquire skill in so doing. Later he (1929b) ran rats in a straight path that expanded in the middle into a diamond formed of an inner and an outer square, thus offering two detour paths, then later

removed the inner square; and from his results he concluded that although the rat when in an open space will orient itself toward the direct route to the goal, it shows no sense of direction in an ordinary maze situation. (The latter conclusion is at variance with our own results as described above under the head of Preliminary Experiments.)

Gengerelli (1929) trained rats to make a left (or right) turn in a pathway, then found that they would make the same general type of turn even when the bifurcation was re-located at a point varying in absolute direction, in distance or in nature of the path; and, inferring the operation of some generalizing function on the part of the animals, held that they do not need a point-to-point correspondence between an old and a new situation, in order to behave adequately in the new. While the inference as to generalization does not bear directly upon our own work, the latter point is clearly in line with it.

White rats were thoroughly trained by Dennis (1929) in a maze consisting of a pathway with two turns; and when the walls were removed, they were not disoriented, but traced paths varying somewhat from that learned between the walls. In this case apparently the maze habit did not depend upon identical stimulations from trial to trial, was not an automatized invariable reacting pattern, but deserved to be called a variable habit.

Bearing more closely upon our own findings is a recent study by Leuba and Fain (1929). They trained white rats in a maze with the living-cage attached to serve as their entrance-box. After learning was completed, they tried rotations of maze-with-living-cage-attached through different angles, and observed no change in behavior; but when they rotated the maze alone through 180° without rotating the living-cage, considerable disturbance was evident. Consideration of the two facts taken together makes it clear that the disorientation when it did occur was not due to the shifting of the visual cues being received from the extra-maze environment; and, since spatial perception through olfactory cues is extremely improbable, we are left to conclude that the living-cage (entrance-cage) became learned by these rats as an orientation-reference point. It is thought

possible and probable that the cage serves as an orientation reference point only for the first few turns and that subsequent turns are determined by the preceding ones in the manner of a proprioceptive reflex pattern. The main outcome of this study is clearly consonant with our own findings, namely, that the position of the entrance-cage is significant for correct orientation in the maze. In further interpretation, however, we must tread warily. To assume, as those investigators have done, that the living-cage serves an orientation function by virtue of being a point of reference, much as "when, in a strange city, we endeavor to keep our orientation by referring to, let us say, the railway station from which we started," may be gratuitous. It would be as fair for us to hold that the animals are simply being tested for retention of a serial habit with and without the learned cues to the first units of that habit—for it is reasonable to hold that exit-from-living-cage-and-entering-into-maze may have become an essential integral part of the whole mechanized serial habit. What the experiment by Leuba and Fain can contribute to our present problem, is, accordingly, limited to their demonstration of the importance of the entrance-box position to orientation in the typical maze problem. It falls short of our own experimental situation in testing only for use of a single specific route, and so in not demonstrating maintenance of orientation throughout varying forms of locomotion.

Such critical analytical studies of the maze habit as we have listed, tending toward a liberalizing of our conception of maze performance, so far as they bear upon our problem offer the following net results: (1) Maze learning is the establishing of a more or less *variable habit.* (2) Sensory guidance in maze running is a *complex of stimuli* of various modalities, and operating in different degrees of spatial definiteness from strictly local stimulus-points to general orienting cues. (3) On the reaction side, the behavior is a *complex of responses* varying all the way from particular momentary flexor and extensor thrusts to longer maintained orientations. (4) The manner of *entrance* into the maze is an *essential*—and may be a crucial—*part* of the whole maze performance.

Rich as these yieldings are in their suggestiveness, they are of limited value for us here; for under the limitations of experimental technique to the learning of a specific pathway, they cannot bear precisely upon our central problem.

III. CHOOSING ROUTES WITHOUT POSITION HABITS

1. The multiple choice method. To obtain evidence as to animals' capacities to perceive spatial relationships Yerkes (1915 a and b, 1917) set a problem that could be solved only by the perceiving of a certain constant relationship obtaining within a series of different situations. *E.g.*, could a given animal learn always to choose the second-from-left-end of a row of open doorways, or the third-door-from-right-end, regardless of what array of open doorways were presented it? Burtt (1916), applying this technique to the white rat, found it able eventually to learn such a simple solution as to take always the first-door-at-right-end but unable to learn to take the second-from-left. From Burtt's description of the behavior of the different rats we can probably generalize by asserting that the "solution" of the first problem was nothing more nor less than a wall-following tendency interrupted upon meeting the first open doorway (subjects A and C) or upon meeting the first closed doorway (D and J). So described, the behavior is far from manifesting capacity to analyze a spatial relationship between different stimuli qualitatively identical. (Later we shall have occasion to refer to an investigation by Maier in which insight was demonstrated for the rat when the parts of the environment differed qualitatively in their stimulus characteristics.)

2. The quadruple choice method. Hamilton (1911, 1916) subjected the concept 'trial-and-error,' that has played so notable a part in the interpretation of animal and human learning, to experimental analysis. Before different species of animals he set a (really insoluble) problem in order to observe their modes of attack, in the form of four identical-appearing doors, of which only one was unlocked and that always a different one in succeeding trials; and he was able to demonstrate qualitatively different levels of efficiency in trial-and-error performance. Now while

his better human and, to some extent, his other primate subjects, displayed "rational inference," and while his mature dogs revealed some tendency to exploration without repetitions, his gray, black, and white rats all made a poor showing in that they tended toward such automatisms as repeating efforts at one and the same door or at two or three doors again and again in the same order. Had the unlocked door been the same one in successive trials, the rats would quickly, of course, have learned to go to it; but where the solution involved more than the fixation of a response to a specific spatial position, they were helpless. In other words, the rats' mode of trial and error attack upon a problem of this sort involves little if any capacity to see into the situation. Let us note, however that insight into Hamilton's problem called for the retention and application of effects from one (the last) single preceding experience out of many, and where the alternative parts of the spatial environment differed very little in qualitative character.

3. The delayed reaction method. Hunter (1912) tested the ability of certain animal species to make a correct spatial choice even after an interval of delay following the appropriate guiding stimulation. After preliminary training to go through a lighted one of three doorways to obtain food (doorways used in irregular order), the animal was held in restraint for a time after the light signal was extinguished. He found that white rats could be restrained for a maximum interval of 10 seconds, and upon release still go to the correct (previously-lighted) doorway. Now, he observed that a rat was able to proceed to the correct door oftener than chance would dictate only on those occasions when, during the delay in the release box, it had remained visibly *oriented* toward the door where the light had appeared. The whole body or at least the head was turned toward the light while it was on, and this posture was maintained until the release came and it simply followed the body or head orientation. Let the overt orientation be disturbed, and the animal on release was at a loss.

So much for the rat. But Hunter discovered that raccoons possessed the ability to go to the correct box even when a wrong

visible orientation was being held at the moment of release, and indeed, when no part of the body had remained constant during the delay interval, which was sometimes even 25 seconds in length. He held that such behavior was ideational in general character, in this case probably being a sensory (kinesthetic) type of thinking, a less developed form than the imaginal thinking of the human adult. More recently (1928a) he has rephrased this interpretation: some *implicit* process, *muscular* in character and set up by the original light stimulus, is maintained in the animal organism in spite of changes in its gross orientation, so that at the moment of release it will serve as a directing cue. Hunter calls this a *symbolic process, i.e.*, a "process which is a substitute, which can arouse a selective response, and which can be recalled if it ceases to be present" (p. 67).

The wording of this definition, taken alone, permits of a variety of more specific descriptions. (a) It would apply to a "*thought*" or to an "*image*" as these words have been traditionally used in human psychology; but neither of these concepts is properly available in the description of animal behavior—at least in an introspective sense. Leuba and Fain's treatment (mentioned *supra*, in II., 2.) of the orientation-function subserved by the constant position of the living cage with reference to the maze might be so interpreted, although—as the present writer understands them—not necessarily so.

(b) The definition would equally well apply to some *central* process, of cerebral, say, or of intra-neural, character; but the very fact of its central location renders its observation difficult or impossible except perhaps by operative technique, and renders interpretative description extremely hazardous in the present status of our knowledge of neural functioning, unless it be made extremely vague. (We will return to this central conception later for further comment.)

(c) The definition quoted is also applicable to some *verbal* or *gestural* process. Psychologists have long been impressed with the enormous rôle played by language in overt conduct and in thinking; and latterly those of strictly objective or behaviorist persuasion have found almost an open sesame into the intricacies

and subtleties of human behavior in the labile, delicately-conditioned, yet powerfully stimulational language and gesture responses. They are symbolic processes *par excellence*. They are indeed, thought processes *par excellence*, if this term be employed objectively, as the present writer has done (1925, 1926, 1928), to refer to implicit responses that are set up (by external or internal stimulation), and that serve in turn as stimuli or cues to further implicit responses or to overt conduct. However, until it can be independently demonstrated that animals such as the rat are capable of making such responses, it is an unwarranted assumption to employ them as explanatory here.

(d) There remains for us yet another way of supplying concrete substance to the notion of some symbolic—or some thinking—process. It seems possible that such a response need not be verbal in any sense nor even gestural. (In fact, the elaboration of these two types is without doubt a primarily social phenomenon having relevance to situations in which inter-stimulations between different organisms is an essential element.) Conceivably, at least, the implicit response may be of a *postural* character, a fragment or segment, let us say, of a total spatial orienting adjustment, the overt components of which may have shifted or changed while the implicit components remain constant. This possibility is so pregnant for our purposes that a fuller treatment is deserved in a separate section.

4. Methods of temporally determined stimuli. His interpretation in terms of symbolic processes Hunter has invoked again (1928b) to explain how the raccoon is able to learn his double alternation maze. This consists of a figure 8 pathway in which the turns are to be taken by the animal circling through it in the temporal order, *r r l l*. As these turns are all to be taken at the middle point of the 8 it is obvious that no external cues, spatial or other, are at hand to guide the animal; and it is forced to learn the order, if at all, through some intra-organic temporal cues. His rats could not learn this (1920).

Failure of the white rat to learn to make correct reactions to temporal relationships between stimuli only was brought out also by Atkins and Dashiell (1921). They presented to their

rats four doorways in which lights flashed once each in varying orders; and tested the animals' ability to learn to go to the doorway that had been lighted first, second, or third, respectively for the different groups of subjects. They obtained no evidence of learning.

To conclude this section: These studies have failed to find in the white rat evidences of behavior of higher types such as are observed in some other species (raccoons and primates). This is particularly true when the relationships to be learned are of temporal more than of spatial order. The rat is apparently dependent upon the formation of spatial position habits in every case. But our survey has not been fruitless. Although white rats performed in ways that were disappointing—as contrasted with their achievement in our own experimental settings—certain modes of interpretation applied to the behavior of other animals may serve us later in envisaging our own problem.

IV. REFLEXOLOGICAL STUDIES

A line of investigation in animal behavior that has had prodigious effect upon the working conceptions of psychology has been the highly detailed experimental analysis of reflexes, leading to interpretation of behavior on more complex levels as explicable by the intra-neural interaction of finely localizable and differentiable reflex arcs. The most noted theorizing in this field is Pavlov's (1927, 1928) consistent assumption of cerebral phenomena as the physiological counterpart and basis for the behavior changes known as the conditioned response. He has gone to some lengths to describe the cortex as a functional mosaic, the various points and areas of which participate each in its own definite way in the determination of the animal's behavior. It is true that he recognizes that even the mosaic is integrated into a complex system in which some sort of unification is continuously achieved; but this integration is envisaged in terms of a multiplicity of component reflex centers. Changes in the animal's unified and organized system of behavior are changes induced by new localized processes upon the totality of older processes occurring throughout the higher centers.

Although he makes few ventures into the field of higher level animal behavior, the analytic work of Sherrington (1906) on spinal reflexes may be considered as having implications in the direction of the interpretation of behavior in terms of the interrelations of specific sensori-motor arcs within the central nervous system. "Alliance" and "antagonism," "reinforcement" and "inhibition," "summation" and "interference," "induction," "reciprocal innervation," "prepotency," etc., etc., are all terms suggestive enough for such a theoretical enterprise.

At once it will be seen that such reflexological explanations of the complexities of behavior fall short of meeting the demands of our experimental findings. Always the behavior is envisaged as complexes of more or less specific and particular reflex actions, even the postural reflexes being so treated; whereas the striking character of our animals' performance is precisely the ability to behave adaptively and successfully throughout many alterations in all the details of the process. Some function operating more independently of detailed stimuli and detailed responses is demanded. This is not to assert that such a function may not be a stimulus-response process; *i.e.*, one much more persistent and lasting than reflex elements such as produce particular twists and turns in the rat's locomotion, and yet one somehow in touch with the latter. But the yieldings of the reflexologists do not on their face furnish us with such a process.

V. MASS ACTION IN THE INTRA-NEURAL FIELD

Latter-day operative and experimental work with the white rat by Lashley (much of which is summarized in his recently published book (1929)) and by Cameron (1928), have borne results pointing emphatically away from the more conventional mode of physiological interpretation of behavior in terms of specific pathways. Lashley studied the effects of many and various extirpations of brain parts upon the capacity of animals to form and to retain maze habits. He found that the maze habit cannot be considered as localized in any special area of the cortex, but that it is conditioned somehow by the quantity of tissue left intact regardless of location. He held, then, that such

higher level integrations must be a function of some more general and dynamic organization of the entire cortical and sub-cortical system. Further, Lashley presented the probability that all parts of the cerebrum, irrespective of their locus, participate to an equal degree and in the same fashion in the maze performance. Cameron's observations of changes in retentiveness and in adaptability to changes in maze pattern associated with cerebral lesions, led him to a somewhat different conclusion than that given in the last preceding sentence: while he agreed that the cerebral cortex was highly integrated, it was not an equipotential system, but a system with certain of its component parts more dominant in certain performances and different ones more dominant in others.

In a more theoretical manner, the explanatory attempts of the *Gestalt* psychologists are in line. Köhler (1926, 1929) has laid emphasis upon the concept of dynamic interdependence within a whole field, demonstrable enough in physics, and urges the interpretation of neural phenomena in such terms.

With this general line of thought we would seem to be approaching more nearly the object of our quest. And such would be an inference to be drawn from the fact that Lashley in connection with his general treatment of maze habits and brain localization makes the following statement (also quoted *supra*, in Preliminary Experiments, III): "The most important features of the maze habit are a generalization of direction from the specific turns of the maze and the development of some central organization by which the sense of general direction can be maintained in spite of great variations of posture and of specific direction in running" (1929, p. 138).

Two considerations, however, give us pause. For one thing, the upshot of the work done by Lashley, Franz, Cameron, and others, is negative rather than positive—is the production of evidence contrary to and invalidating the conventional conception of local determination within the neural system rather than evidence having positive, constructive suggestions. No intraneural function has been explicitly demonstrated, but only some general characters that such function would have, if and when it has been observed on its own account.

In the second place, any explanation exclusively in intra-neural terms would seem to be inapplicable to our problem: highly important peripheral functions must be playing some of the leading rôles. Where the behavior is made up of spatial adjustments, and these are varying enormously and in intimate dependence upon momentary positional and orientational conditions, it would seem unreasonable to assume that a wholly intra-neural mechanism could in an autonomous manner direct the routing of the animal's locomotion. Rather, it seems more reasonable to posit the moment-to-moment contributions of peripheral or somatic receptors—especially space receptors—as essential contributors to the determining of this routing.

VI. FINDING ROUTES BY INSIGHT

1. Brief studies. Higginson (1926) found in the behavior of white rats a characteristic which he believed directly comparable to the elaborate perceptual performances of Köhler's primates. Using a circular maze, he placed a snugly fitting door at the usual opening from alley 2 into alley 3. On each trial he kept this door closed until the animal had passed it and proceeded on down to the blind at the end of alley 2, then removed it so that on the animal's return it found it opening into the next alley—thus forcing it to run 6 feet of excess distance. After 100 such trials the doorway was left open from the first; and of his 9 rats 5 immediately turned in at the now open door, while the other 4 did so on the next trial. This prompt readjustment to eliminate the excess running was interpreted by Higginson as a case of insight, wherein the animal showed visual apprehension of the total situation.

To the present writer it seems that a factor still needing to be checked in this experiment is the novelty of the new opening presented the animal; for it is a common observation that unless it is running pell-mell a white rat is all-too-likely to turn in at any new opening along the way. It should further be noted in passing that Valentine (1928) has failed to confirm by essentially the same technique the findings of Higginson.

Helson (1927) found further evidences suggesting interpretation

in terms of insight. A white rat had formed a persistent position habit of entering always the left of two doors. To break this the light (positive signal) was shown repeatedly in the right doorway. The process by which the animal then learned to choose the right door only took the form of a rather gradual straightening out of its path from the original circuitous form (straight to the left door then out and around in semicircle and into right door) to the final direct form (bee line from point of release to right door).

Helson describes also an interesting performance of rats when in an emergency. They were being trained in a discrimination box, with grids laid upon the floors of the compartments, and punishment by electric shock administered both when the animal entered and when it left the wrong compartment. He observed that two rats upon finding themselves in the wrong compartment and having received a shock when entering, finally came to make their exit not by returning out through the door and over the live grid but by climbing the high middle partition and dropping directly into the food compartment.

To comment on the two cases of Helson's:—The former surely lends support of doubtful strength to the insight theory, for there was manifested not a sudden re-structuring of the whole situation; although it might possibly be taken as illustrative of the "dynamic field" line of interpretation, entertained in the same psychological quarters. Concerning the second case, alternative interpretations seem possible, but analysis is difficult without more details concerning the apparatus and procedure.

What is more interesting is that the brief experiments mentioned in this section all become especially relevant to the problem of our own studies, namely, spatial orientation determined by the position of the food box.

2. The method of detour. More striking evidence of capacity for insight into the spatial aspects of a situation has been recently presented by Maier (1929), in a protracted series of experiments at Berlin and Michigan. His general technique was an adaptation of Köhler's "roundabout" method. *E.g.*, a rat was accustomed to obtaining its food at a certain corner of a table top; it was also trained to run without error in an elevated maze,

independently of the table. Then a wire netting was interposed between rat and food on the table; the elevated maze runway was connected up to the table top so that it could be entered from the rat's side of the table, and led around the netting to the food; and also some false runways were connected to the table top. It was observed that in all or nearly all cases the rats, after running about the table top a little while in vain efforts to get to the food, would rather abruptly make for the entrance to the maze, and so around to the food; and on the second trial would proceed at once and directly to the maze entrance and around. Rats untrained in the maze failed to show this directness.

Another sample set-up was as follows. A rat that was familiar with a room was specially trained to climb a certain one ringstand of several, to an elevated pathway leading to food—the floor territory involved in this training being strictly limited in scope. Then when released in a central point in the room, the animal would make directly for the ringstand to which it had been trained, and, scaling it, take the elevated path to food. Rats untrained to a specific ringstand would reach and climb any one in an unpredictable manner; and rats unfamiliar with the room, though trained to a specific ringstand, found the specific one only in a chance number of cases.

The interpretation given this behavior was that rats showed capacity to *combine essential elements* of *two different situations* in a *novel* and adjustive *fashion* to reach an objective: they could reason. "The solution is a continuous whole and is directed toward an end."

While such an interpretation is certainly relevant and covers the facts, the present writer is not altogether convinced that simpler explanations are not possible. When a rat in a baffling situation turns more or less directly to that particular avenue (maze entrance, etc.) to which it has been trained, it seems possible to describe this in terms merely of the *familiarity* of maze or ringstand (enhanced stimulus) without assuming any anticipation of the ultimate goal to be reached thereby. Or again, the direct run to maze entrance or ringstand when these are found

in the environment looks suspiciously like a positive response to a situation-detail previously accompanied by food; and this is capable of interpretation as a conditioned response, rather than as revealing insight.

Several special points in Maier's study have interesting bearings upon our own. For one thing, he observed that in its trips across the floor of a room a rat does *not* learn it as a *particular pathway*. This is taken to show that the floor is adopted only as a means to an end, as a bridge over a gap.

Comments concerning the sensory basis of the rat's behavior bears directly upon the orientation problem. "The rat's knowledge of a situation must be comparable to that of visual spatial relations. An ape or a human can adequately respond to a round-about solution which is new, when it has a spatial view of the whole situation. The rat must gain this sort of knowledge of the whole situation by exploring all parts of it with the use of kinaesthesis, touch, and its inadequate vision" (pp. 87–88).

In one experiment Maier's animals were offered opportunity to jump down from the elevated U-shaped pathway leading from point of release to the food and to use the floor for a short-cut. But no decided orientation to food was shown at first, although the animals in 2 or 3 trials came to make the short-cut.

Further evidence against a gross orienting toward the food was contained in the observation that when a new maze was used offering alleys turning toward and turning away from the direction of the food box (location of which the rats had had ample opportunity to learn previously by climbing about the wire food enclosure), no tendency was manifested to take the former more than the latter. Now, here, let us parenthetically note, it would seem that the case for insightful behavior falls down completely. When an animal "knows" the location of the food, yet upon coming to a bifurcation in a new pathway shows no tendency to go in that direction; and will do so if it is the only pathway in which it has been previously trained—then surely its directions of locomotion are not determined by any seeing-into the whole situation but by the "loading" of the one-pathway-out-of-several through conditioning.

We may close this section with the *conclusion* that some experimental studies have tended to show capacity in the white rat to adjust itself to new situations in a rational (insightful) manner; but that the evidences as yet are not criticism-proof.

3. Some more general descriptive formulae. The *Gestalt* psychologists are emphasizing reactions to structured situations, to situations-as-wholes, and for them learning typically involves insight in the sense of re-structuring of the situation-as-a-whole (especially Köhler, 1926, 1929). The (more or less patterned) stimulation of the individual may come to arouse eventually a new and more appropriate patterned response, by virtue of an intermediate perceptual process in which the situation-as-a-whole is re-structured. Undoubtedly, our animals were learning to react to a certain structural character of their problem—the general direction from entrance to exit—even through changes of many sorts and with a surprising adaptiveness. In the language of the *Gestalt* school, we might say that they were learning "to structure the general maze situation in a manner that made the resultant configuration transposable in a striking degree from one concrete situation to another."

Shepard's theory of association pattern learning (Shepard and Fogelsonger, 1913) has been applied by Maier (1929) to the behavior of his white rats (cf. *supra*, VI, 2), in which they showed capacity to combine the essential elements of two different situations in a novel and adjustive fashion. After an animal had become familiar with the spatial relations, *A* (starting point) to *b*, *A-c*, *A-d*, *A-e*, and has also learned a certain sequence of spatial items, *b-1-2-3-F* (food), then when placed at *A*, with the two whole spatial patterns articulated at *b*, it will proceed fairly directly to *b* and on to *F*. Thus a new pattern or spatial *Gestalt*, from *A* to *F*, is formed out of two other *Gestalten*, *b* to *F*, and *A* to *b* or *c* or *d* or *e*. The concept of *Gestalten* is thus taken to be a necessary assumption in the interpretation of learning as more than mere trial-and-error, as reasoning.

Tolman (1927, 1928a) has recognized the importance of some kind of spatial insight on the part of the white rat, as throwing light upon researches of his students, including Blodgett (1925),

Yoshioka (1928), Elliott (1928), Williams (1929), and Hsiao (1929). When facing a learning task an animal starts with three initial postulations concerning (a) the character of the end object, (b) the character or the present surrounding means, and (c) the position of the former with reference to the latter. (Even Thorndike's cat in the problem box for the first time reveals some general postulation of the c type in its varied efforts to get *out* of cage.) The course of learning is essentially a process of arriving at a new improved postulation as to the position of the end-object. Tolman calls this "insight;" and he holds that the term is applicable to solutions obtained by trial and error as well as to those obtained by "foresight," the former being attained through overt behavior, the latter without overt behavior. In a still more general discussion (1928b) Tolman has claimed the right to employ the term "purpose" in a true natural science manner to refer to that condition of an animal whereby acts that lead toward a specific end-object persist and may get learned—a condition reducible to complicated sets and patterns of adjustment that get set up within the organism.

Now it must be said of these and other applications of the principles of *Gestaltung* and of insight, that they help us admirably to envisage our problem. For purposes of formulation they are of service. However, in our search for the particular processes or mechanisms at work in the behavior of our white rats, we receive no help from these theoretical sources. To say that the animal comes to structure its maze situation, or that it comes to combine essential elements of two patterns, or that it is behaving purposively because the observer can note that its behavior is determined somehow by an improved postulation as to the position of the end object—these expressions serve to mark off the behavior in question in an interesting and suggestive way rather than to offer any hint whatever of *just how* this behavior comes about.

We complete our survey of contemporary experiments and theories on animal behavior with special reference to the white rat, without finding a precise parallel to our own observations.

Some of the studies have tended to award the rat only a very lowly psychological status, indicating its dependence for spatial adjustments upon position habits of quite local and specific character. Some of them, on the contrary, have brought out a variability in spatial adjustments, also a capacity to orient spatially toward an ultimate objective, and to react to situations or patterns of stimuli as wholes. And moreover, the observations of other animals than the rat have brought to light characteristics of behavior that may be fruitful in interpreting complex behavior by this animal as well. The more theoretical yieldings of our survey have furnished us with a few very general manners of description of animal behavior and animal learning; but they fall short of precise indications of processes and mechanisms that might serve to explain analytically the behavior of our white rats.

CONSTRUCTIVE SUGGESTIONS

We have not, in our canvass, found a precise parallel to our own observations, nor a theory which readymade will furnish their complete explanation. But interpretative effort is demanded at this time; and purely speculative and hypothetical suggestions may be hazarded now, for the sake of whatever value they may have in stimulating further theoretical and experimental research.

One character of our animals' behavior—as especially examined in Formal Experiments IV.—is that it is in some peculiar way dependent upon the position of the food box. The mode of entering the maze being absolutely the only thing constant through all runs, it follows that the animals' uniform success in finding their way to the food objective must be in some sense a *function of this initial orientation at the entrance.* Our experimental techniques having eliminated the possibility of exteroceptive sources of guidance beyond the entrance alley, we are forced to seek such further guiding agency in some intra-organic factor or factors.

I. A FORWARD-GOING TENDENCY IN LOCOMOTION

One way of conceiving of an internal source of guidance is in terms of a natural tendency of any animal, and under any but very special conditions, to maintain roughly a forward direction in its movements.[7] The animal, let us say, tends to keep on going in a general direction already established rather than to turn aside, and especially rather than to double back. In an unpublished experimental study we have observed that a white rat runs a maze much more quickly when turns of no more than 90° are required than where turns of 180° are called for; and also that

[7] Schaeffer (1928) has shown that in all the genera and species examined by him, from Amoeba to man, locomotion tends to follow spiral paths; but the spirals generally have a relatively large radius of curvature, and we may consider this as (for our purposes) an unimportant modification of the general observation of a tendency toward locomotion in a consistent direction.

it runs one more quickly when 90° turns alternate right and left than when the turns follow in such order as to produce U's in the true path. Consistently with this we elsewhere (1920b) have noted the observation that a white rat is more likely to enter a blind alley opening straight ahead than one opening at the side of the true pathway, in about the ratio of 5 to 4. The principle may be briefly put: When a rat is already in locomotion, it is more likely to continue approximately in the same direction of that locomotion than to turn aside sharply or to return. Our rats manifested from the first some tendency to run on up a straight alley in which they were already running.

As an economical principle of mechanics in animal locomotion this seems understandable enough; but we have to consider more than the mechanics of the running apparatus. Always in some measure are there deeper seated motivational factors; and notably so in the process of learning a way through a maze. And as a matter of fact, in our studies the rats came to show an apparent forward-going tendency in food box direction only after the first two or three trials; *i.e.*, after they have become *motivated* by finding food to *learn* the general direction from entrance to exit. Thus, there may have been a double rôle played by this forward-going function in the case of our animals: from the first they tended somewhat more to run along alleys than to make turns; and, with practice on the problem set them, they tended to keep going in food box direction more than to reverse.

But we cannot accept a more general animal tendency (such as forward-going) as the sole and central controlling factor in the behavior we are examining, and we must consider the possibilities of a more specific factor. Is it possible that at the time the animal is entering the maze (the only detail of the maze to which it is reacting in one constant manner) some particular implicit process could be established or aroused which then serves as a guiding factor in the further movements of the animal?

II. A PERSISTING SEGMENT OF THE INITIAL ORIENTATION

Let us consider the possibility that when one of our animals first enters our criss-crossing alternative-alley maze the conditions

of its entrance—passage up the single straight entrance alley—are such as to develop in the animal, in successive trials, some form of motor posturing or set, which comes to function as a preparatory orienting response to the maze situation. This orientation, now, being in a constant direction at the entrance doorway, and the food incentive being located in a constant position, it may be supposed that the rat will come to learn the relationship between the two.

So far is plain sailing; but we have yet to take account of the many and striking variations in the animal's behavior between the two points of entrance and exit. Certain it is that any gross orientation of the body determined by the mode of entrance will be disturbed by any variation in the route taken through the maze on successive runs. Can there be any *segment of the initial orientation* at the entrance that might be maintained (implicitly, of course) in spite of irregular alterations in the gross overt segments, a phase or piece of the whole original attitude that might remain constant through inconstant and varying processions of steps and turns? The animal, 'set' by the position of the entrance alley, enters the maze and encounters obstacles that force it to turn right or left. These turns are taken, and the animal continues for varying distances in these forced directions; but not the entire original set is changed, and the unchanging segments furnish the afferent cues by which the animal is stimulated to make correcting changes in direction of locomotion.

This conception is suggested by the behavior of animals in Hunter's experiments on delayed reactions (*cf. supra,* III, 3). Whereas some species were plainly seen to preserve gross body or head orientation during the interval of delay, other species reacted successfully without any observable orientation; and it is reasonable to suppose that some orienting or "pointing" function was operating in the latter but in an implicit way. A very simple form of such function would be a contraction of some local muscle or muscle-group that does not participate in the mechanics of extensor- and flexor-thrusts of the running movements and turning movements themselves. It may be noted in passing that when human adults are threading a maze, whether in

the streets of a strange city or in an amusement park concession, one source of orienting cues is provided kinesthetically, often arising from grosser postural functions such as consistent tiltings of head. This is probably of the same order of phenomenon as revealed in the simpler automatograph experiment where the spatial direction of an object being attended to is revealed by the tracings from involuntary movements.

A very much higher level of guidance by a segment of initial orientation is that where symbolic processes of the language type are involved. Upon entrance to a maze a human subject may formulate the direction or end-object in explicitly verbal terms—"over there" or "straight ahead;" and this formulation may be repeated from time to time to serve as a guiding cue.

If the white rat in our experiment did, in fact, employ some sort of persisting segment of initial orientation, it is most likely that it was of some order or grade lying somewhere between the two extremes just mentioned.

III. REINFORCING AND INHIBITING INFLUENCES UPON SPECIFIC MOVEMENTS

An outstanding phenomenon in neurology and psychology is the effect of one neuro-muscular process upon others in the way of positive and negative accelerating effects. As James once put it: "A process set up anywhere in the centers reverberates everywhere, and in some way or other affects the organism throughout, making its activities either greater or less." Sherrington's noteworthy contributions to neurology center about an experimental analysis of some of the types of interaction between reflexes (1906); and of these, two of the most striking and central are the reinforcement and the inhibition of one reaction unit by another.

From Sherrington we learn how one specific reaction may be reinforced by another specific reaction, as when a flexion reflex of the hind leg excited by stimulation of a toe of the same foot is accelerated by simultaneous stimulation applied to the crossed fore foot, to the tail, or to the crossed pinna. We learn also how one reaction may be inhibited by another specific reaction, as

when a scratch reflex is set aside by the noci-ceptive arousal of a flexion reflex in the homonymous fore leg or in the opposite hind leg. These positive and negative influences originate also in postural reactions, such as those involved in the maintenance of stance; as when the arousal of a postural extensor thrust in a given leg inhibits the appearance of the scratch reflex of the same leg, particularly if noci-ceptive excitation is inhibiting the postural reaction of the opposite leg. From various studies of the human knee jerk we know how a specific phasic reaction may be both facilitated and inhibited by organic conditions of wider scope—sleep, emotional (visceral) attitude, concentrated attending, active digestive processes, etc.—in which responses of postural or tonic character are predominant. Finally, the phenomena of compensatory movements involved in the corrections for disturbed bodily equilibrium, offer numerous instances of the dominance (reinforcing and inhibiting) of phasic reactions by whatever postural reactions are being called out.

With these various phenomena in mind, it becomes possible to hypothesize reinforcing and inhibiting influences exerted by the persisting segment of initial orientation in the rats' behavior as observed in our experiments—influences operating to facilitate any steps and turns allied with this orientation segment and to interfere with any steps and turns antagonistic to it. Or, to describe this more concretely:—the way in which the animal is originally "headed" or set upon entering the maze has some enduring effect, some part of the "heading" or set is retained; and as it faces the varying conditions of walls and openings during its running within the maze, tendencies to movements into openings that are in line with the direction of the retained set are strengthened while movements in directions opposite to it are weakened.

IV. COMPENSATORY CORRECTIONS

A possible factor operating to support and strengthen both the forward-going tendency in animal locomotion (I) and the facilitating and inhibiting of specific movements by a postural set (III), would be the occurrence of compensatory corrections for changes

in direction of locomotion. A prominent phenomenon in experimental work on equilibration is the prompt arousal and execution of compensatory reactions. In the literature most attention in descriptions and in later discussions of this line of work has been given to disturbances of balance, irregularities of head or body position with reference to the vertical, and to the kinds of movements made to correct for such disturbances. But the original observations, from many experimental studies, include also data on alterations of direction of locomotion resulting directly or indirectly from lesions to the equilibrating apparatus. Unilateral lesions are followed by the so-called "forced" movements, such as locomotor progression in small circles, and these have been interpreted as the result of the loss of some of the compensatory movements. For instance, if every incipient turn of body to the right arouses compensatory leg movements turning it in the reverse direction, while incipient turns of body to the left arouse no such movements, the net result will be a consistent alteration of locomotion in leftward direction (Ladd and Woodworth, 1911).

Now, our suggestion here is that something of the same functioning may operate in the case of an animal set going in a given direction, then forced aside for a short distance: the externally forced turn of the body away from the "bee line" that represents its initial orientation may arouse compensatory movements or tensions in leg, neck, and other muscles, that serve to right the animal's direction again when the external obstruction has been passed. Such a factor should probably be thought of best as supplementary and supporting hypothetical guiding factors that have already been described—the forward-going tendency of an animal in locomotion, and the facilitation and inhibition of particular movements made in locomotion by a persisting posture or set.

V. PHYSIOLOGICAL MECHANISMS INVOLVED

The above-described explanatory principles are based more or less directly upon the operation of bodily organs and mechanisms that have had their share of direct experimental study.

The equilibrating and orienting functions of the *vestibular-cerebellar apparatus* have had much attention. (*Cf.* Griffith, 1922.) The following possibilities in the way of application to our problem warrant consideration. When an animal is given a certain orientation upon entering our maze, a definite position of the labyrinthine apparatus is a part of the whole posture. Right or left turns then forced by the maze partitions lying across its path occasion specific excitations of these receptors. In the course of a very few trials with a well-motivated animal, the initial labyrinthine stimulus-complex becomes established as an enhanced and controlling cue. Further, a prominent phenomenon in experimental work upon equilibrating functions is the prompt arousal and execution of compensatory reactions; which fact we can incorporate in our hypothesis here, by supposing that disturbances of locomotion-direction forced by the maze partitions and the consequent stimulation of the labyrinthine receptors arouse compensatory corrections of locomotion-direction at the next open cross-pathway (or, when the forward-going propensity is dominant, at a later open cross-pathway). It may or may not be significant for this hypothesis of learning, to bear in mind that nystagmus and other compensatory movements occasioned by labyrinthine stimulation show practice effects notoriously.

Again, the rôle of stimulations arising from disturbances of position of the *soft contents* of the body and, more especially, from changes in *muscle-tendon-joint* apparatus, is generally recognized as probably considerable. Interoceptive and proprioceptive impulses conveyed to cerebellar or other lower-brain centers contribute heavily to the afferent side of the picture of equilibration and orientation.

There is another character of muscle functioning that may be significant for our purpose—*muscular tonus.* For one thing, it appears established that the tonic condition of muscle may be continuously maintained in spite of intercurrent phasic contractions, the two being the expression of distinct systems of innervation (Sherrington, 1915, Wilson, 1924, Hunt, 1925,

Herrick, 1926)[8]; and so an original posturing in the form of a muscular set is not necessarily wholly interrupted and broken up by moment to moment reactions. In the case of our animals, the point could be more concretely put: a tonic posturing set up at entrance to the maze is not necessarily wholly destroyed by the (forced) phasic turnings and steppings to right or to left

A special aspect of muscle tonus that would be a significant contribution to our problem may be called tonus-differentials. It is an incorrect assumption that the height of tonicity of any muscle group adequately represents the height for all muscle groups of the body, *i.e.*, that the tonicity level at any given time is one level for all the musculature of the organism as a whole. On the contrary, while certain muscle groups are thrown into heightened tonus, other muscle groups may remain at lower levels; and so the posture and the behavior of the body as a whole at any one time would be a function of these differing amounts of tension. For example, Sherrington (1915) describes the squatting of the frog as a picture of tonus in flexor more than in extensor muscles of the hind legs; and he (1906) quotes Ewald as showing how each labyrinth maintains tonus especially in the neck and trunk muscles and extensor-abductor limb muscles of the homonymous side. Moreover, medical clinics offer pathological cases in which permanent contractures of certain specific muscle groups are found consequent upon brain disease.[9] To apply this general point to our problem: a rat upon entering our maze and turning right or left may conceivably have aroused in it a greater tonicity in those muscle groups tending to carry it toward the food box (*i.e.*, in a certain direction from the entrance) than in those tending to carry it elsewhere; and (as touched upon in the preceding paragraph) this relative difference may persist regardless of the particular steps and turns forced by the maze obstructions.

[8] The assumption of two independent kinds of muscular contraction, a tonic and a phasic, is brought out strikingly in the claims of Hunt that the muscular fibrillae are phasic in function while the sarcoplasm is tonic, and of Hunter and Royall that the muscle fibers are of two sorts, the white which are phasic and the red which are tonic.

[9] For these and other suggestions on differential tonus I am indebted to correspondence with Professors W. H. Howell and C. Judson Herrick.

Now, we must keep in mind, of course, that in all likelihood, any such mechanisms and functions as we have been naming do not operate in isolation, but that the behavior of the rat is determined by their interplay. Thus, if rat x on one trial takes such a course as the "a" or the "t" type (*cf.* Figure 7), in which it runs for some distance in an alley before making a turn, it may be manifesting a greater relative potency (for the time being) or the forward-going tendency (I); when on another trial it takes a route of the "f" or the "o" type in which it zigzags through the central portion of the maze it may be revealing a greater relative potency of some persisting segment of the initial orientation (II) operating in positive or negative way upon the specific movements (III), this being reinforced by compensatory tendencies (IV).

SUMMARY

In a variety of experiments on maze learning by the white rat, instituted for the most part to study quite other problems, a curious phase of behavior was observed. The rat when running a maze early shows the influence of some direction-orienting tendency that operates independently of specific stimuli to particular local movements, and enables it, when physical conditions permit, to pursue pathways never before trod, yet without false turns nor wrong directions. In the preliminary experiments, this tendency appeared as a tendency to make errors in those blind alleys that happened to open up in the general direction of the food box much more than in those opening in the reverse direction—and this regardless of the direction taken by the true path in that vicinity.

To isolate this function was the problem of several formal researches. In 1925, rats were trained in an open-alley maze offering a great number of criss-crossing alternative and equal-length pathways from the entrance to the food box exit. Each animal learned soon to adjust to the situation not by fixating some particular pathway but by running in the general direction of the exit, now by one succession of turns and now by another, so that in a series of trials it followed a variety of different routes from entrance to exit—each route being taken without error and frequently without any previous practice therein.

The same study was repeated in 1927 with experimental check upon sensory cues. Exteroceptive sources of guidance (visual, auditory, and olfactory cues both from without and from within the maze) were eliminated by rotations, by changes of materials of which the maze was constructed, by air currents from false food boxes, etc. Finally, in a repetition of the experiment in 1929, the experimenter was eliminated as a (theoretically possible)

source of minimal cues. The conclusion follows that the performance must be controlled intra-organically.

Meanwhile, in specially modified experiments it was being demonstrated that the orientation function is dependent for one thing upon the particular manner in which the animal enters the maze. The direction of entrance was varied specifically or was left to chance; and, there was a striking preponderance of trials in which the animal followed out its initial orientation.

We have shown, then, that when an animal is learning a maze it is not simply integrating a chain of conditioned reflexes, not organizing a simple serial pattern of discrete units. Some more general function is being established. The results are in line with contemporary trends; and in the hope of finding explanatory concepts with which to describe them, a survey has been made of contemporary experimental and theoretical studies that might have any bearing upon our problem. Careful survey fails to bring to light closely similar observed cases that have received analysis; and explanatory concepts in the field have proved too general.

Purely speculative and hypothetical suggestions are then hazarded. When a rat first enters the maze there may be set up some kind of kinesthetic or organic posturing or set (developed in preceding trials), determined by the animal's position when proceeding up the entrance passage way. Then, as the animal traverses the maze and encounters obstacles forcing it to turn right or left, a persisting segment of the initial orientation may inhibit specific stepping movements antagonistic to it and facilitate those consonant with it. Compensatory correcting movements when an animal is forced out of line may strengthen this selective function. Meanwhile, the animal tendency to continue in a forward-going direction may account for long runs in alleys before turns are made.

Whatever the merits and demerits of this and of similar theories, the experimental data remain as clear evidence for some more general function in animal learning than the chained sequence of discrete action-units.

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PREFERENTIAL MANIPULATION IN CHILDREN*

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CONTENTS

The purpose of this investigation was to ascertain the preferential use of the hands as manifested by children of pre-school age in motor activities of various types and under varying conditions. Responses to controlled situations, in the form of three tests of hand preference, were studied, as well as responses involved in daily activities of the child's own choice. An attempt was also made to evaluate the tests used as means of determining the extent and degree of preferential handedness. In an earlier investigation (9) the author summarized previous studies in this field and pointed out that there are apparently degrees of preferential handedness rather than the two definite manual types as conventionally designated. This view is likewise advocated by Downey (6), who holds that "the conventional classification of individuals into right-handed and left-handed furnishes very little information about their manual habits," and that "all degrees of unidextrality (the use of one hand in preference to the other) exist."

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The subject of handedness is one of intense interest to both layman and scientist. The interest shown by the layman is due to the practical nature of the subject, and numerous are the problems arising therefrom which the scientist is called upon to solve. Contributions to the literature of handedness, however, are not restricted to scientific investigations, but include many popular articles as well. Consequently, although much has been written on the various topics relating to the preferential use of the hands, only a small proportion thereof has real scientific value. An historical survey of the various questions involved in a study of handedness reveals also that considerable diversity exists regarding these questions, not only with reference to theory, but likewise in the conclusions derived from experiments conducted by different investigators.

A much disputed question is that concerning the nature of handedness—whether it is an inherited or an acquired characteristic. Various theories have also been advanced to account for the method by which the trait is inherited, as well as the means through which it is acquired. A review of the various theories of handedness is given in Parsons (13).

Several investigators have made controlled observations regarding the origin and development of handedness in the infant; however, these investigators, also, have failed to agree with reference to conclusions derived from their respective studies. Baldwin (1) and Woolley (16) each maintained, on the basis of results obtained in their respective studies of the origin and development of handedness in an infant, that handedness is something more than an acquired habit, and that its cause must be sought in inherited physiological grounds. Baldwin (1) made a series of controlled observations on his child from the age of 4 months to 10 months, in which he noted the preferential use of the hands in reaching for objects placed before it. He reports a "distinct preference" for the right hand under pressure of muscular effort in the 7th month. The observations made by Woolley confirmed those of Baldwin in this connection. She states that during the 7th month, reaching called out the use of the right hand almost exclusively, though little if any distinction in the

use of the hands could be detected at that time in activities not requiring effort. By the 9th month, Woolley states the child was "evidently right handed." She concluded that "right-handedness is a normal part of physiological development, not a phenomenon explicable by training."

Dearborn (5) conducted a series of observations on a child from the time of its birth until its third birthday, and reports that the use of the right hand gradually became more habitual after the first five months, until at the age of 14 months the right hand was used "much more than the left," despite the fact that "sporadic efforts were made to make the child left-handed and so practically ambidextrous later on."

Watson (15) conducted a number of experiments on infants, consisting of a series of anthropometric measurements, observations of the grasping reflex, measurement of the relative activity of the right and left hand respectively in a given period of time, and observation of the frequency with which each hand was used in reaching for objects. He reports that no steady and uniform handedness was shown in any of these experiments, and concludes that "there is no fixed differentiation of response in either hand until social usage begins to establish handedness."

Gesell (8) maintains that unidextrality is based on inherent constitutional, rather than on cultural factors. The existence of germinal factors, he states, is suggested by the fact that left-handedness is sometimes a familial trait; however, he does not regard this as conclusive, as left-handedness may be a "secondary by-product of a more fundamental familial trait involving vascular or anatomical peculiarities." He cites the case of an infant who showed evidence of left-handedness in the very first day of his life by vigorously sucking his left hand, and who, despite the efforts of his parents to train him during early childhood in the use of the right-hand, nevertheless evidenced the persistence of left hand tendencies upon his entrance into school. Gesell regards this as an evidence of the futility of systematic social conditioning in overcoming inherent left-handedness, and as an indication that the inherence of left-handedness may date from birth.

A number of investigators have concerned themselves with the devising of tests of "native" handedness. Among the various methods used for this purpose are the tests of motor control: dynamometer, which tests strength of grip; tapping, which tests the comparative quickness or rate of movement of the two hands; tracing, which measures accuracy and precision of movement; steadiness, which measures the inhibition of movement of the hands.

Beeley (3) conducted a series of investigations for the purpose of devising a means of detecting native handedness, using the tapping, steadiness, and tracing tests. The subjects were 100 right-handed and 14 left-handed subjects, ranging in age from 6 years to 15 years, and in school grade from the 3rd to the 6th, inclusive. He found that the tapping test in which finger movement was used is superior as a method of diagnosing handedness to the tapping test in which either arm or wrist movement was used; and is also superior to either the steadiness test or the tracing test, for diagnostic purposes. The reasons for the superiority of the tapping test in which finger movement was used, are as follows: first, its diagnoses give a distribution of handedness which correlates more perfectly with the known facts (namely, the child's own statement, corroborated by the teacher); secondly, it reveals a greater difference in dexterity between the two sides of the body.

Jones (12) conducted an extensive investigation on 20,000 individuals, ranging in age from stillborn to centenarian, in order to establish standards for determining born handedness and adopted handedness. He proceeded on the assumption that if an individual either is born with or has acquired unequal potentialities on the two sides of the body, there must be some evidence that will be revealed by the "tape line." With the aid of an instrument termed a brachiometer, he measured the length of the ulna plus, the humerus, circumference of the palm and wrist, circumference of the forearm relaxed and contracted; and of the arm relaxed and contracted. Examination of the data, he states, indicated that "born handedness is revealed by the measures of the bones of the arm, the major arm having the larger bones;

and this evidence is present at birth. Adopted handedness is shown by the muscle swell, the adopted or preferred arm having the higher percentage of muscle swell."

Beeley (3) conducted a series of experiments with the Jones brachiometer on 123 young children in order to determine the reliability of this test for diagnosing born-handedness. On the basis of results obtained, Beeley concludes that, first, the theory upon which the Jones tests are devised is not valid in all cases, as many cases of extreme right-handedness were diagnosed by this test as left-handedness, and conversely; secondly, the distribution of handedness does not agree with the known facts; thirdly, in most children the difference between the length of the bones of the two arms, as shown by these results, is so slight that it would seem to be somewhat hazardous to determine the life habits of a child solely upon such evidence.

Parsons (13) maintains that handedness is caused by eyedness, the favored hand being on the same side of the body as the sighting eye. On the basis of this theory he conducted a series of tests upon 877 grammar school pupils, ascertaining their sighting eye by means of an instrument devised by him termed a manoptoscope. Of the total number of children tested, 608 used the right visual line for sighting. With four exceptions, all the right-eyed persons were right-handed. Two of the four exceptions admitted trouble with the left eye, "the original sighting eye," according to Parsons. However, this almost unbroken relationship between eye and hand is not shown in the case of the left-eyed pupils, numbering 257. Only 32 of this number confessed to being left-handed. Parsons assumes that, in the case of those who were diagnosed as left-handed on the basis of their left-eyedness and who claim nevertheless to be right-handed, their sighting eye had been changed due to ocular troubles, or their handedness had changed due to trouble with the hand. Cuff (4) criticizes this explanation as being theoretical only. On the basis of the results obtained by administering the manoptoscope test to 146 school children, Cuff also maintains that the test as devised by Parsons is unreliable for individual diagnosis.

More recently, attention has been directed to a study of dextrality types other than the two conventional divisions of "right-handed" and "left-handed," cognizance being taken in this study of the tendency to prefer one hand in activities of certain types, and the other hand in activities of other types. Thus, while there are a number of people who use their right hand exclusively for all unimanual acts and for the so-called "business" end of bimanual acts; and a smaller number who use their left hand exclusively; there are many individuals who apparently show divided preference, using the right hand for activities of certain definite types, and the left hand for activities of other types.

Rife (14) has classified individuals into six dextral types on the basis of the following preferential usage: (1) right-handed in unimanual activities and the "business end" of all bimanual activities; (2) right-handed in unimanual activities, and left-handed in the "business end" of all bimanual activities; (3) right-handed in unimanual activities, and in the "business end" of activities of the "first rank," such as golf or batting, but left-handed in the "business end" of the "lesser" acts, such as shoveling and sweeping; (4) left-handed in unimanual activities and in the "business end" of all bimanual activities; (5) left-handed in unimanual activities, and right-handed in the "business end" of all bimanual activities; (6) left-handed in unimanual activities, and in the "business end" of activities of the "first rank," such as golf or batting, but right-handed in the "business end" of the "lesser" acts, such as shoveling and sweeping.

In an extensive study of dextrality types, Downey (6) classified 1500 individuals according to Rife's scheme, with some slight modification. The distribution of dextrality types indicated that, in the group of normal individuals studied, more than half use the left hand wholly or partially for bimanual operations. Interesting sex differences were noted. The percentage of men using the right hand exclusively is 41%; the percentage of women in this dextral group is 36.6%. The majority of the women, namely 51.3%, were right-handed unimanually and in bimanual acts of the "first rank;" whereas 34.6% of the men were in this

group. The percentage of men using the right hand unimanually and the left hand bimanually is 17.3%; the percentage of women, 8.6%. In the group of 257 left-handed studied, 25% of the men and 32% of the women were left-handed in all activities, unimanual and bimanual, the balance of both sexes being right-handed in some or all of the bimanual acts.

Downey investigated with reference to these dextral types for the following: eyedness and handedness; the dominant thumb; the spade foot; handedness types and degree of unidextrality; structural differences and handedness types; handedness types and intelligence; orientation and eyedness; temperament and handedness; handedness and speech defects. Downey indicates that her conclusions with reference to these specific problems are "tentative only;" the main purpose of her investigation being exploratory, to suggest fields for more intensive experimental work.

More recently Downey (7) made a study of the dextrality types exhibited by 49 pre-school children ranging in age from 2 years 9 months to 5 years 10 months, and noted that exactly the same dextrality types were shown by these children as by the adults previously studied, although "a slightly larger per cent of unstable reactions were found in the case of the children." From this she draws an inference that dextrality types are probably inborn, since they are "very different in form, appear with different frequencies in the two sexes, and are manifested very early in life."

In the investigation previously cited (9) in which a study was made of the performance of 60 children in four series of tests of visual-motor coördination, the author found that but 25% of the group consistently made superior scores with a given hand in repeated trials of all four test series; and that the remaining 75% were consistently superior with the right hand in all trials of one or more test series, and with the left hand in the remaining series, or were inconsistent in manual superiority in yearly retrials of one or more test series. This variation of preferential handedness in motor activities of different types is suggestive of "types" of handedness. The author also pointed out in this study the existence of variation in degree of preferential handed-

ness on the part of the subjects who were consistently superior in the performance of a given hand in all four test series. This variation was shown not only with regard to the difference in degree of superiority of the favored hand as evidenced by different individuals in a given yearly test; but also with reference to the tendency on the part of some children to decrease, and of others to increase, in degree of superiority of the favored hand with increase in chronological age.

Experimentation

This study consists of a series of observations on a group of thirty-six pre-school children[1] at the Child's Institute of the Johns Hopkins University. The types of observations made were as follows:

I. Three forms of manual tests were given under different experimental conditions for the purpose of ascertaining the preferential use of the hands in the situations presented. The results of these tests were compared with the so-called "native" handedness of the child. The criterion of "native" handedness adopted was the report by the parents of the manual bias exhibited by the child in daily activities. The hand favored in daily activities is referred to throughout this study as the "preferred" hand, whereas the hand not so favored is termed the "non-preferred" hand.

II. A study was made of learning by the non-preferred hand, and the transfer of training, if any, to the habitually preferred hand.

III. A training method was developed for practicing left-handed children in the use of the right hand in motor activities involving gross motor coördinations, as well as those involving the minute motor coördinations.

IV. Ten daily observations of 10 minutes each were made on each child in order to ascertain the preferential use of the hands, and the consistency of such preference, in daily activities of the child's own choice.

[1] All of the children were not used as subjects in each observation series, as this study extended over a period of four months or more, and some of the children were at the Institute for a two-week period only.

I. TESTS OF HANDEDNESS

The three tests employed were of the type in which manipulation may be either unimanual or bimanual. The situations imposed in the respective tests were as follows: in the first test, equal opportunity was provided for the use of either hand; in the second test, an inconvenience was imposed upon the use of the preferred hand; in the third test, rapid, spontaneous choice of hand was required.

Thirty subjects were used, ranging in age from 2 years to 6 years 8 months. While this number was not constant throughout all three tests, there was a nucleus of 24 subjects who performed in all tests and sections thereof. For the purpose of analysis, these subjects were divided into three handedness groups, namely, Right-handed, Left-handed, and Ambidextrous, this division being made on the basis of the report of the parents. These reports were confirmed in the case of twenty-one of the children by data gathered by the experimenter in the daily observation series reported in the fourth section of this study. Of the subjects who performed in all tests, 16 were right-handed, 6 were left-handed, and 2 were ambidextrous. The number of subjects in each age-group was as follows:

HANDEDNESS GROUP	AGE-GROUP				
	Two	Three	Four	Five	Six
Right	3	6	3	4	—
Left	—	1	1	2	2
Ambidextrous	1	—	1	—	—

In tests 1 and 2, the performance of several of the two-year olds was not considered with that of the remaining children in the group as these little ones did not complete the tests; however, the data regarding them were analyzed in so far as possible.

Test 1: The Marble Board

The activity involved in this test was that of picking up and placing, one by one, a series of similar objects. The condition

under which this test was given offered equal opportunity for the use of either hand.

Apparatus and procedure. The apparatus used was a Dunlap marble board, made of ebonized wood, $11\frac{1}{2}$ inches square and $\frac{7}{8}$ of an inch thick. This board was mounted upon two strips of ebonized wood, 11 inches long, $1\frac{3}{4}$ inches wide, and $\frac{7}{8}$ of an inch thick. The board contained 100 depressions of half inch diameter each, arranged in ten rows or columns of ten depressions, the depressions being equidistant from each other. Two marble boards were used in this experiment, each one being placed upon a separate table. The height of the table with the marble board on it was such that the child could lean over it and place the marbles with ease even on the top row. The tables were placed two feet apart. Directly in front of the marble board on each table was a box containing 100 white agate marbles. Thus, the marbles and the board were so arranged that manipulation by either hand was equally favored.

Two children were brought into the experimental room at the same time and were told to stand, one at each table, in front of the marbles and the marble board. The experimenter sat on a chair placed between the two tables, in order to prevent the children from stopping in their activity to watch each other. Instructions were given as follows: "Here is a marble board and a box of marbles for each of you. I want each of you to place your marbles in your board just as quickly as possible, and see who finishes first! Wait until I say 'Go'! Ready! Go!"

The performance of only one child of a pair was observed, and this child was then used as a competitor for the next performer. The competitor for the child observed in the first pair was a former attendant at the Institute, and her record was not included as part of this experiment. The element of competition was employed as an incentive toward spontaneous manual choice. The investigator observed which hand was employed by the child in picking the marbles from the box, and which hand was used in placing them in the recesses of the board.

Results. Variation was shown in all three handedness groups in the form of manipulation adopted, not only in the performance of different children, but also, in many cases, within the per-

formance of a given subject. Thus, while some children adopted a unimanual method throughout the test, others consistently used a bimanual method, and still others varied between these two types of performance. The bimanual method assumed four forms, in two of which the function of the two hands was different in kind, and in two, the function of the two hands was the same in kind. The methods adopted were as follows:

1. Picking and placing a sequence of marbles with one hand.
2. Picking the marbles (one at a time, or several) from the box with one hand, and placing them with the other.
3. Picking several of the marbles from the box with one hand, passing to the other hand to hold, and placing with the first hand, one by one.
4. Alternately picking and placing a marble with one hand, then with the other.
5. Picking and placing a marble with each hand simultaneously.

Right-handed group

There were 17 children in this group of 19 who completed the test. The average per cent of marbles manipulated according to each of the methods noted, by the group who completed the test, is as follows:

	METHOD 1		METHOD 2		METHOD 3		METHOD 4	METHOD 5
	(a)	(b)	(a)	(b)	(a)	(b)	Alt.	Simul.
Hand used to Pick	R	L	L	R	R	L	R L	R L
Hold					L	R		
Place	R	L	R	L	R	L	R L	R L
	80.2%	4.8%	6.7%	0.6%	1.8%	0	1.2%	4.7%

The average per cent of marbles picked and the average per cent placed by each hand, without reference to a specific method, is as follows:

	RIGHT HAND	LEFT HAND
Picked	85.5%	14.5%
Placed	91.6%	8.4%

The tendency of this group was toward a pronounced preference for the use of the right hand in both picking and placing the marbles. Fifteen of the seventeen children who completed the test used the right hand in manipulating from 75% to 100% of the marbles, the remaining two children showing no preference for either hand. Consistency in manual choice for the "preferred" right hand in picking and in placing all of the marbles was noted on the part of 9 children, representing approximately 54% of the group. Of these nine children, eight used the right hand exclusively to pick and place the marbles in a strictly unimanual form of manipulation; and one child used the right hand exclusively to pick and place the marbles, although she varied from a strictly unimanual performance to a form of the bimanual method in which the left hand held the marbles which had been picked, a number at a time, by the right hand, and passed by that hand to the left to hold. The remaining eight children varied the strictly unimanual method in which the right hand was used exclusively, with one or more of the other methods noted in which the left hand functioned exclusively, or in either picking or placing the marbles. Five of these eight children adopted the unimanual method favoring the right hand in the manipulation of at least the first fifty marbles, and then used other methods, frequently alternating thereafter between the use of the first method and the subsequent ones.

Fifteen children in this group started their performance by picking and placing the marbles with the right hand, one started picking and placing with the left hand, and one started by picking and placing a marble with each hand simultaneously.

In some instances, conditions were noted which may have been influential in producing a deviation from a dominant method. For example, one subject, when picking and placing a sequence of marbles with the left hand, would sometimes, on reaching toward the extreme right of a row, pass the marble to the right hand to place. A second subject, who used primarily the method of picking the marbles from the box with the left hand and passing them to the right hand to place, would occasionally, on reaching to the extreme left of a row, place the marble with the left hand in which it was held.

Two of the three two-year olds in this group did not complete the test. They became disinterested after having placed twenty or twenty-five, one of them discontinuing the task, although he apparently retained his interest in the marbles as objects to handle and roll about. The second subject reluctantly continued until she had placed fifty marbles, making a wry face during the latter part of her task. Then, suddenly announcing that she didn't want to play any more, she turned away from the board and ran from the room. This latter subject used the right hand exclusively to pick and place the fifty marbles. The first subject referred to was ambidextrous in his method, favoring first one hand, then the other.

Left-handed group

The average per cent of marbles manipulated according to each of the methods noted, by the group of six children who completed the test, is as follows:

	METHOD 1		METHOD 2		METHOD 3		METHOD 4	METHOD 5
	(a)	(b)	(a)	(b)	(a)	(b)	Alt.	Simul.
Hand used to Pick	R	L	L	R	R	L	R L	R L
Hold					L	R		
Place	R	L	R	L	R	L	R L	R L
	20.3%	31.3%	1.3%	1.7%	0	28.7%	5%	11.7%

The average per cent of marbles picked and the average per cent placed by each hand is as follows:

	RIGHT HAND	LEFT HAND
Picked	30.3%	69.7%
Placed	30 %	70 %

The general tendency on the part of the group was toward a pronounced preference for the use of the left hand in both picking and placing the marbles, although there was individual variation.

While none of the children in this group consistently used their habitually "preferred" hand throughout to pick and place the marbles, four children showed a marked preference for the left hand, picking and placing at least 80% of the marbles with that hand. Two of this group of four favored primarily the uni-manual method of manipulation, picking and placing each marble with the left hand without any aid from the right hand; however, the other two subjects favored the bimanual method of picking up several marbles with the left hand, passing them to the right hand to hold, then taking them one by one from the right hand and placing them with the left hand. The two six-year-olds in this group showed no preference for the left hand, one of these children using primarily the method of picking and placing a marble with each hand, simultaneously, the other child definitely favoring the right hand, picking and placing 94% of the marbles with that hand and 6% only with the left hand. These two six-year-olds were kindergarten pupils.

All of the children in this group started their task by picking and placing the marbles with the left hand.

The two-year-old in this group did not complete the task, manipulating but 34 marbles. He showed no consistent preferential handedness, but varied his choice every two or three marbles.

Ambidextrous group

The two ambidextrous children who completed the test both showed a marked preference for the left hand, one subject using it exclusively to pick and place all of the marbles, the other subject varying this method to some extent with the other methods of manipulation in which the right hand functioned in whole or in part. The average per cent of marbles picked and the average per cent placed by each hand is as follows:

	RIGHT HAND	LEFT HAND
Picked	15%	85%
Placed	15%	85%

The two-year-old in this group manipulated but 17 marbles. No marked favor was shown to either hand, as this subject would alternately pick and place a few marbles with one hand, then a few with the other hand.

All three children began their task by picking and placing with the left hand.

Two-year-olds. The peg board

As the two-year-olds, with but one exception, had failed to complete the manipulation of the total number of marbles, and had apparently regarded the marbles as objects to roll, or to pick up and let fall through the fingers, another test was adopted for them, namely, the peg board. This, like the marble board, was arranged in such a way that manipulation by either hand was equally favored. The board used was made of selected stock of bass wood which did not indicate any grain. Twenty-five holes of $\frac{3}{8}$ inch diameter were bored therein, these holes being arranged in five rows or columns of five holes each, and were equidistant from each other. The board was 9 inches square, and three-quarters of an inch thick. The pegs which fitted into the holes were one-quarter of an inch in diameter, and 2 inches in length. The board and pegs were lacquered.

The peg board was placed upon a table sufficiently low to permit the child to lean over it and place the pegs with ease. The box of pegs was on the table directly in front of the peg board, thus being equally accessible to either hand. The children were brought into the room singly, and not in pairs as in the marble board test. The child was told to stand at the table in front of the pegs and peg board and was instructed as follows: "Do you see this peg board and these pegs? I want you to put the pegs into the board just as fast as you can!" This test was given to each child daily over a three-day period.

The subjects consisted of 3 right-handed children, one left-handed child, and one ambidextrous child.

The forms of manipulation employed were similar to those noted in the marble board test. In the right-handed group, all three children showed a decided preference for the right hand,

although they differed to some extent in the degree to which this bias was exhibited. The right hand was strongly favored by all three subjects in placing the pegs, subjects B and D using that hand exclusively, and subject C using it in placing all but 3 pegs. Subject D likewise showed a marked preference for the right hand in picking the pegs, using the left hand to pick but one of the total number of seventy-five pegs; while subjects B and C used the left hand to pick approximately 20% of the pegs. Subjects B and C showed some daily variation, each of them having used the right hand exclusively to pick and place the pegs on one day, while on the other two days they used the left hand to pick some of the pegs.

The one so-called left-handed child in this group of two-year-olds strongly favored the right hand in picking and placing the pegs on the first and second days; however, on the third day his manual choice was approximately equal for each hand.

The ambidextrous child favored the right hand to a greater extent than the left in both picking and placing the pegs; however, the degree of preference for the right hand in placing them was very small. This subject also showed variation in successive daily performances, using the right hand primarily on the first day for both picking and placing the pegs, favoring the right hand more frequently for picking and the left more frequently for placing on the second day, and on the third day favoring the left hand to a greater extent than the right in both picking and placing.

Test 2. The Formboard

The activity involved in this test was that of picking up, one by one, a series of objects or forms and placing them within the corresponding recesses of a formboard. The conditions under which the test was given involved a convenience to the use of the habitually preferred hand in the manipulation of half of the forms, and an inconvenience to the use of the habitually preferred hand in the manipulation of the other half of the forms. It was planned to ascertain whether, in the manipulation of the forms inconveniently placed with reference to the preferred hand, but

conveniently placed with reference to the non-preferred hand, the use of the "preferred" hand would persist despite the inconvenience; or whether the child would resort to the use of the "non-preferred" but convenient hand.

Apparatus and procedure. The apparatus used was the Cornell adaptation of the Seguin formboard. This modification of the Seguin formboard was well adapted to the conditions of this experiment in view of the fact that the forms fit into the recesses of a series of removable blocks, the position of which could be arranged to suit the requirements of this test. The wooden blocks containing the recesses, and which comprised the formboard, were placed from left to right in the following order:

First row—elongated hexagon, triangle, star
Second row—cross, circle, elongated diamond, lozenge
Third row—square, half circle, rectangle.

This arrangement was made for the purpose of dividing the board, in so far as possible, into a right half and a left half. Thus, the right side of the board contained recesses for the star, the lozenge, the rectangle, the triangle, and the elongated diamond; and the left side contained recesses for the elongated hexagon, the cross, the square, the circle and the half circle. The half circle extended slightly to the right of the median line of the board.

The blocks corresponding to the recesses were placed on the table, five at the right and five at the left of the formboard. Thus, in manipulating the forms lying at the side of the formboard corresponding to the "preferred" hand, termed the "preferred" side, a convenience was offered to the use of that hand, in that the forms were readily accessible to it; however, in manipulating the forms lying at the side of the formboard opposite to that corresponding to the "preferred" hand, termed the "non-preferred" side, an inconvenience was offered to the use of the preferred hand in that its use would involve reaching across the board. Four trials were given under somewhat varying conditions with reference to arrangement of forms at the right and left sides of the board. The arrangements were as follows:

Trial 1. The five blocks placed at the right of the formboard corresponded to the five recesses in the right section of the board, and were placed in a consecutive order, from top to bottom, those corresponding to the recesses at the extreme right of the board coming first, then those corresponding to the adjoining column. The order was: star, lozenge, rectangle, triangle, elongated diamond. The five blocks at the left of the board corresponded to the five recesses in the left section of the formboard, and were likewise placed consecutively, in so far as possible, those corresponding to the recesses in the extreme left column being placed first, then those corresponding to the recesses in the adjoining column. The order on the left side was: elongated hexagon, cross, square, circle, half circle.

Trial 2. The five blocks lying at the right of the formboard were those corresponding to the five recesses of the left side of the formboard, placed in the same order as in trial 1. Those lying at the left of the formboard corresponded to the five recesses in the right side of the formboard, placed in the same order as in trial 1. In other words, while the order in which the blocks were placed in the two columns was the same as in trial 1, the columns were reversed.

Trial 3. The five blocks lying at the right of the board corresponded to the five recesses at the right side of the formboard, as in trail 1; however, the order of the blocks was changed. The order was as follows: elongated diamond, rectangle, star, lozenge, triangle. Likewise, the five blocks lying at the left side of the board corresponded to the five recesses of the left side of the board, as in trial 1; however, the order of the blocks was different from that in the first trial. The order was: circle, square, elongated hexagon, half circle, cross.

Trial 4. The order in which the blocks were lying in the two columns was similar to that in trial 3; however, the columns were reversed. Thus, as in trial 2, the blocks in the column at the left of the formboard corresponded to the recesses in the right half of the formboard, while those in the column at the right of the formboard corresponded to the recesses in the left half of the board.

Each subject was given the four trials in consecutive order. The interval between trials was three minutes. During this period the experimenter removed the blocks from the recesses of the formboard and placed them at the sides of the board in the proper order for the next trial. The subject was in an adjoining room between trials. There was a sliding board in this room

and most of the children availed themselves of the opportunity for a slide before taking the next test. When the subject first entered the room, the blocks were arranged at the sides of the formboard, on the table, in the order given for trial 1. The table on which the formboard and blocks were placed, was in line with the door through which the child entered the room, so that the child's approach to the board should be directly from the front, in so far as it was possible to arrange this experimentally. After he had taken his place before the formboard, he was instructed as follows: "Let me see how fast you can put these blocks into place!" When the first trial was completed, the child was sent into the adjoining room, as noted above, until called for the second trial. He again entered the room through the door directly in line with the table and formboard, with the blocks to the right and left of the board. Instructions were given before each trial, although they were scarcely needed, as in all trials after the first the subject usually ran into the room when called, and running to the table, immediately began placing the blocks without waiting for instructions. The children were, without exception, greatly interested in the formboard.

The following observations were made by the experimenter of the performance of each subject: (1) the hand with which the subject picked up and placed the blocks which were lying at the right of the board, and those lying at the left of the board, in each trial; (2) whether the subject placed all of the blocks lying at one side of the board before placing any from the opposite side, or whether he shifted back and forth, from one side to the other; (3) whether the blocks were properly placed in their corresponding recesses; (4) whether the subject endeavored to finish his performance as quickly as possible.

It was noted that in many cases a child would pick up a form, with a given hand, place it above the recess with that hand, and then assist in placing it within the recess with the other hand, often pounding it in with that hand. Unless a form was definitely passed by the hand which picked it from the table to the other hand for placement in the recess, the second hand was not credited with placing the block.

Results.—

Right-handed group

The average per cent of blocks lying at the *right* side of the board which were picked and placed by each hand in each trial, as well as in the total number of trials, is given below.

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick	100%	—	94%	6%	94%	6%	94%	6%	95.6%	4.4%
Place	100%	—	94%	6%	94%	6%	94%	6%	95.6%	4.4%

It appears that when objects were conveniently located with reference to the preferred hand, a pronounced preference was shown by all of the children in this group for that hand. Fourteen of the seventeen children in this group who had all four trails, representing approximately 84% of the group, consistently used the right hand in all four trials in picking and placing the blocks lying at the right of the board, regardless of whether the forms lying at the right of the formboard corresponded to the recesses in the right half or in the left half of the board. Three subjects, representing approximately 16% of the group, favored the right hand consistently in three trials and the left hand in one trial. The trials in which the left hand was used was a different one for each child. The 2 two-year-olds who completed only the first trial, both used the right hand to pick and place the forms lying at the right.

The average per cent of blocks lying at the *left* side of the formboard, which were picked and placed by each hand in each trial, as well as in the total number of trials, is as follows:

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick	34%	66%	48%	52%	48%	52%	42%	58%	43%	57%
Place	42%	58%	54%	46%	54%	46%	44%	56%	48%	52%

The group average indicates a greater degree of preference for the left hand than for the right, particularly in picking the forms from the table, however there are wide individual differences. The degree of bias for the right hand in manipulating objects lying at the left, thus offering an inconvenience to the use of the habitually "preferred" hand, ranged from 100% choice for that hand to zero. The children tended to fall into three groups as follows: (1) those who, despite the inconvenience offered to the use of the right hand, nevertheless showed a pronounced tendency toward the use of that hand; (2) those who favored to a pronounced degree the "convenient" left hand; (3) those who showed no marked degree of preference for either hand. The second group was the largest, as 8 subjects, representing approximately 48% of the total number of subjects, used the left hand in manipulating from $66\frac{2}{3}$% to 100% of the total number of forms lying at the left in the four trials. Next in size was group (1), as 6 subjects, representing approximately 35% of the group, favored the right hand in manipulating from $66\frac{2}{3}$% to 100% of the total number of forms lying at the left. Three subjects, representing approximately 17% of the group, showed no marked favor for either hand.

Consistency of choice for a given hand in the total number of trials was shown by 5 children in this group, 3 of whom used the right hand exclusively to pick and place the five forms lying at the left of the board in all four trials, and 2 of whom used the left hand exclusively in these trials. The remaining 12 subjects in this group varied their manual choice in one or more trials. Four of these twelve subjects consistently used a given hand in manipulating the five forms lying at the left in any single trial, however they varied from trial to trial, using the right hand consistently in one or more trials, and the left hand consistently in the remainder. Four subjects consistently used a given hand in manipulating the five forms in each of three trials, but in one trial they varied their choice, manipulating one or more forms with the right hand and the remainder with the left. Four subjects were consistent in the use of a given hand in one trial only, and varied their manual choice within each of three trials. Thus,

while 54% of the subjects were consistent in the use of a given hand in each of the trials, considered separately, relatively few maintained consistency in manual choice throughout all four trials.

The five children who maintained consistency in manual choice throughout all four trials, in manipulating the forms at the left of the board, were all four-year olds. No significant age differences were noted with reference to the hand most frequently used.

Left-handed group

The average per cent of forms lying at the *left* side of the board, which were picked and placed by each hand in each trial, as well as in the total number of trials, is as follows:

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick..........	—	100%	—	100%	—	100%	—	100%	—	100%
Place.........	—	100%	—	100%	—	100%	—	100%	—	100%

In this group, as in the Right-handed group, when objects are conveniently located with reference to the "preferred" hand, there is a pronounced preference for the use of that hand. The six children in this group who completed the four trials, all consistently used the left hand in picking and placing the blocks lying at the left of the formboard in all four trials. The two-year old who performed only one trial, likewise used the left hand exclusively in manipulating the forms lying at the left.

The average per cent of forms lying at the *right* side of the formboard, which were picked and placed by each hand in each trial, as well as in the total number of trials, is as follows:

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick...............	47%	53%	83%	17%	50%	50%	60%	40%	60%	40%
Place.............	40%	60%	73%	27%	40%	60%	40%	60%	48%	52%

Some variation was shown with reference to the hand used in picking the forms and that one used in placing them. With reference to the total number of trials, the average per cent of blocks which were picked by the right hand predominates over the average per cent picked by the left hand, while in placing the blocks, the average per cent of left hand choices predominates slightly over the average per cent of right hand choices. This predominance of right hand choices in picking, and of left hand choices in placing, is not consistently shown, however, in each separate trial. As in the Right-handed group, there are wide individual differences.

Thus, when forms conveniently located with reference to the "non-preferred" hand, but inconveniently located with reference to the "preferred" hand, are manipulated, considerable variation in degree of bias for the "preferred" left hand was manifested. The degree of bias for the "inconvenient" left hand, as evidenced in the performance of the subjects in the total number of trials in manipulating the forms lying at the right of the board, ranged from 70% to 30%. The range of variation does not reach the limits attained by the Right-handed group in either direction, as none of the children consistently favored their "preferred" hand, nor did any favor their "non-preferred" but convenient hand exclusively, in all four trials. Thus, while none of the children in the Left-handed group indicated the strong degree of bias for their "preferred" hand which was evident in the performance of several children in the Right-handed group, on the other hand none of them adapted so thoroughly to the use of the "preferred" hand as did some of the children in the Right-handed group.

As in the Right-handed group, the children tended to fall into 3 groups as follows: (1) those who, despite the inconvenience offered to the use of the "preferred" hand, nevertheless showed a pronounced tendency toward the use of that hand; (2) those who favored to a pronounced degree the "convenient" but non-preferred hand; (3) those who showed no marked degree of preference for either hand. One child favored the left hand in manipulating approximately $66\frac{2}{3}\%$ of the forms; 3 children used the right hand in manipulating at least $66\frac{2}{3}\%$ of the forms; and 2

children showed no marked preference for either hand in picking the forms, although one of these two used the left hand primarily in placing them.

None of the children in this group showed a consistent preference for either hand in the total number of trials, nor did any of this group consistently use a given hand within each separate trial. Four children in this group consistently favored a given hand in one or more trials, and varied their manual choice within the remaining trials; and two subjects varied their manual choice within each of the four trials.

Ambidextrous group

The average per cent of forms lying at the *left* of the board, which were picked and placed by each hand in each trial, and in the total number of trials, is as follows:

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick	13%	87%	7%	93%	—	100%	—	100%	5%	95%
Place	13%	87%	7%	93%	—	100%	—	100%	5%	95%

Although there is a slight variation in degree of left hand bias in the manipulation of the forms lying at the left, all three of the subjects in this group showed a marked preference for the left or "convenient" hand. One child consistently favored the left hand in all four trials, and two children favored the left hand consistently in three trials, and in one trial used the right hand to manipulate one or two forms.

The average per cent of forms lying at the *right* of the board which were picked and placed by each hand in each trial and in the total number of trials, is as follows:

	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4		TOTAL	
	R	L	R	L	R	L	R	L	R	L
Hand used to Pick	100%	—	80%	20%	87%	13%	67%	33%	83%	17%
Place	100%	—	47%	53%	67%	33%	67%	33%	70%	30%

A greater extent of variability is exhibited here than in the manipulation of the forms lying at the left of the board, although here, also, the three subjects all tended to favor the hand conveniently located with reference to the desired object to a greater extent than the hand not so conveniently located. One child used the right hand consistently in all trials to pick up the blocks, and in 3 trials to place them, but varied her manual choice in placing them in one trial; one child favored the right hand in picking up and placing all forms in two trials, in picking up all forms in one trial and in placing all in one trial, although she varied her manual choice in these two trials otherwise; and one child used the right hand exclusively in two tests in picking and placing, favored the left hand exclusively in one trial, and varied her manual choice in one trial.

Thus, all three children in the Ambidextrous group favored the hand which was more conveniently located with reference to the desired object to a greater extent than the hand not so favorably located; although when the left hand was the convenient hand, the preference for it was evidenced to practically the same degree by all of the children, namely, almost exclusively; whereas when the right hand was the convenient hand, there was some difference in degree of preference for the right hand.

Transfer of blocks from one hand to the other. There were 3 children in the Right-handed group, 4 in the Left-handed group, and 2 in the Ambidextrous group, who occasionally transferred a form from the hand which had picked it from the table, to the other hand for placement. In the Right-handed group, these transfers occurred only when the forms lying at the left of the board were manipulated; and the transfer was in every case from the left hand which had picked up a form, to the right hand for placement. The transfers which occurred in the Left-handed and Ambidextrous groups were all found where blocks lying at the right side of the formboard were manipulated. The transfer in these cases was always from the right hand, which had picked up the block, to the left hand for placement. As in the case of the Right-handed group, these transfers were distributed over the total number of trials, and not confined to any one of them.

Thus it appears that, in both the Right-handed and Left-handed groups, transfers were made only when the non-preferred hand had picked up a form conveniently located with reference to it; and the "preferred" hand was then favored with the placing of the form. No age difference was noted in this respect, as this tendency was noted on the part of one or more of the subjects in each of the age groups.

Skipping from side to side in manipulating the forms. In the Right-handed group, five subjects adopted the method throughout all four trials of manipulating all of the forms lying at one side of the formboard before placing any from the opposite side. The remaining twelve children in this group skipped from side to side in one or more trials. In the Ambidextrous group, all three subjects skipped from side to side in one or more trials. Three subjects in the Left-handed group consistently manipulated all of the forms lying at one side of the formboard before placing any from the opposite side throughout all four trials. The remaining three subjects skipped from side to side in one or more trials.

The number of subjects in each group who skipped from side to side in the various trials was as follows:

HANDEDNESS GROUP	FIRST TRIAL	SECOND TRIAL	THIRD TRIAL	FOURTH TRIAL
Right	1	8	4	9
Left	1	3	1	2
Ambidextrous	1	2	0	1
	3	13	5	12

It will be noted that the tendency to shift from side to side occurred with much greater frequency in the second and fourth trials, in which the forms were lying at the side of the formboard opposite to that section which contained their corresponding recesses. No age differences were noted in this respect, as one or more of the subjects in each age group adopted this method of shifting from side to side.

Speed and accuracy of placing the forms. The children above

three years of age all made an apparent effort to place the forms as quickly as possible. The majority of the subjects above three years also apparently discriminated before placing the forms in their respective recesses. Three subjects over the age of three years used the trial and error method of manipulation during the first two trials, placing a form over first one recess, then another. Two of these subjects succeeded in placing all of the forms correctly in these two trials, as well as in the last two trials in which they apparently discriminated before placing the forms. One of these subjects made several errors in the first two trials, although in the last two trials all of the forms were placed by him correctly.

Only one of the five children under three years of age succeeded in placing all of the blocks correctly. These subjects used primarily the trial and error method, placing a block over one recess, then over the other, endeavoring to force it in, and frequently leaving the block lie above the wrong recess. Time counted for little with this group, as no effort was made by them to speed the performance, and a great deal of time was spent in laughing and chatting about where a given form would be placed.

There were two children in the Right-handed group and one in the Left-handed group who consistently started, in all four trials, to place first the forms lying at the side of the formboard corresponding to their preferred hand. While the remaining children in both groups varied in different tests, starting at the right in one or more tests, and at the left in the remainder, the tendency on the part of the majority of the subjects in both of these groups was to start manipulating the forms lying at the side corresponding to their "preferred" hand in the greater number of trials.

Analysis was made of the performance of those subjects who started first to manipulate the forms at the right in one or more trials, and in the remaining trials started first to manipulate the forms at the left, in an endeavor to ascertain whether there was any relation between the side at which the child started to work, and the arrangement of the forms at the side of the formboard

in the four trials. It was noted that in the Right-handed group, the cases in which the forms at the left of the board were manipulated first were distributed among the four trials, and not confined to the second and fourth trials, in which the forms at the left of the board corresponded to the recesses in the right side of the formboard. Likewise the cases in which the blocks at the right were first manipulated were distributed throughout the four trials. This was also true of the performances of those children in the Left-handed and Ambidextrous groups who showed variation with respect to the side from which they started in different trials. Thus it appears that, on the whole, the arrangement of the blocks at the side of the formboard opposite to that section which contained the corresponding recesses, in trials 2 and 4, did not direct the choice of blocks placed first in these trials, although this factor may have operated in individual cases.

An analysis was made of the performance of those subjects who exhibited diverse or varied manual choice in picking up the forms lying at the "non-preferred" side of the formboard, this diversity being manifested with reference to entire trials as opposed to other trials, or with reference to the manipulation of individual forms within specific trials. For example, an endeavor was made to ascertain whether there were any factors consistently accompanying the performance of a left-handed child who, in picking up the forms lying at the right of the formboard, used the left hand in one or more trials and the right hand in the remaining trials; or, who used one hand to pick up and place one or more forms within a given trial, and the other hand to manipulate the remaining forms. This analysis was likewise made with reference to the performance of the right-handed children with blocks lying at the left of the board. Variations in manual choice exhibited in the Ambidextrous group and by the three children in the Right-handed group who, in manipulating the blocks lying at the right of the board, used the left hand in one trial, were also included in this analysis.

The following conditions were found to occasionally accompany manual choice:

1. The hand with which a child started to manipulate the forms corresponded to the side of the board from which the forms were first taken.

2. The hand with which a child started to manipulate the forms at one side was used consistently throughout the placement on both sides in a given trial.

3. Variation in placement of forms by the experimenter at the side of the formboard in different trials was accompanied by variation in the child's manual bias.

4. Shifting from side to side in manipulating the blocks in a given trial was accompanied by the use of the same hand after the shift as before.

5. Passing a block from the hand which picked it from the table, to the other hand for placement, was followed by the continued use of the second hand in manipulating the next block.

6. The necessity of reaching for a block at the top of the column of blocks lying at the side of the formboard opposite that of the "preferred" hand sometimes called forth the use of the preferred hand, although the non-preferred hand was used in that specific test to manipulate all other blocks lying on that side.

While any one of these factors was occasionally found to accompany a given choice of hand which varied from the choice primarily favored, it cannot be stated conclusively that these factors were causal, as none of them was invariably present when variations in manual choice were noted. Also, the same manual choice did not invariably follow whenever a given factor was present, either in the performance of different children or in the performance of the same subject in different trials. For example, in one trial a child may have started placing forms lying at the left of the board, using the left hand. In another trial, the same child may have again started placing the blocks lying at the left, but this time the right hand was employed. Also, with reference to shifting from side to side, while in some cases the same hand was used in manipulating the first block only which was placed after the shift as was used immediately prior to the shift, in other cases the change from side to side was accompanied by the use of the same hand throughout the trial for manipulating the

forms on both sides; and in still other cases, where a shift from side to side was made, the manual preference invariably followed the side from which the blocks were taken, that is, the right hand manipulated the blocks lying at the right of the formboard, and the left hand manipulated those lying at the left side.

Test 3: The Picking-up-toy Test

The activity performed in this test was that of running as swiftly as possible for a desired object and bringing it to the experimenter. The condition imposed upon the subject by the nature of the task was rapid, spontaneous choice of hand. The test comprised three distinct sections, differing from each other in certain respects which are noted in the discussion of each specific section. A series of choices was made in each section, in order to ascertain consistency of manual preference in repetitions of the task.

Section 1

Two objects were employed as stimuli for response in this section of the test. The purpose was to ascertain whether the child would grasp one of the objects with the habitually preferred hand, pass it to the non-preferred hand to hold, then grasp the second object with the preferred hand; or whether he would reach for the objects with both hands simultaneously. That is to say, would the child give to the habitually preferred hand the active part of the performance, and to the non-preferred hand the passive function? Or would the two hands function in the same type of performance? If the latter method were used, would the preferred hand be favored in point of time in that it would reach out before the non-preferred hand?

Apparatus and procedure. The objects used were two orange rubber kitty cats, about one foot in height, of the type which expanded when air was blown into them. They stood in upright position, on the hind legs, with the front legs extended in armlike fashion. They were dressed in bright colored garments which called forth the admiration of all of the children. In fact, without exception, the kitty cats were a source of extreme delight to all.

They were called "Flopsy" and "Mopsy," the names having been bestowed upon them by one of the children and speedily adopted by the rest.

These kitty cats were placed side by side in a tin basket which was painted in gold and black. They were so arranged that the head and upper part of the body of each cat projected above the rim of the basket. Thus the cats were visible and easily accessible to the subjects. The basket was then placed at one end of the room, about two feet in front of a window, and six feet from the experimenter. The cats were resting against the side of the basket nearest the window and thus were directly facing the experimenter and subject.

The children were brought into the room in pairs and were given turns alternately in running for the kitty cats. The experimenter endeavored to place the child directly in line with the cats so that, in so far as it was possible to arrange them, conditions would favor a frontal approach to the desired objects. After releasing her steadying hold, she gave the following instructions: "When I say 'go,' I want you to run just as fast as you can to the basket and bring me the kitty cats. Do you understand? Now, Go!" The experimenter recorded the following: (1) the position assumed by the child at the basket—whether he stood directly in front of the kitty cats, toward the right, or toward the left; (2) the hand which first reached out and picked up a kitty cat; (3) whether any transfer was made of the cats from one hand to the other; (4) the direction in which the child turned after securing the cats. After the first child completed the first trial, the cats were replaced in the basket by the experimenter, and the second child was given a trial. Alternate trials were taken until each child of a pair had three trials. Three daily series of trials were given, making a total of 9 trials for each child.

Results. The various forms of manipulation employed, together with their corresponding symbols, are as follows:

RL(S)—both hands function *simultaneously*, each one grasping a kitty cat.

R— right hand seizes both cats at the same time.

R-R— right hand seizes one kitty cat, passes to left hand or arm to hold; then right hand seizes the second kitty cat.
R-L— right hand first grasps a cat, then the left hand grasps one.
L-R— left hand first grasps a cat, then the right hand grasps one.

The average per cent of trials in which the respective forms of manipulation were favored by each handedness group is as follows:

	RL(S)	R-L	L-R	R	R-R
Right-handed group	73.6%	19.4%	4.9%	1.4%	0.7%
Left-handed group	92.6%	7.4%	—	—	—
Ambidextrous group	66.7%	33.3%	—	—	—

It will be noted that no preference was shown, in any of the three handedness groups, to either the right or left hand with reference to type of function; nor was either hand favored to any significant extent in point of time, in so far as the experimenter was able to ascertain by direct observation; as the method of manipulation primarily employed by practically all of the children was that of reaching for and grasping a kitty cat with each hand simultaneously. Of the 16 subjects in the Right-handed group, 5 used the simultaneous method exclusively; 8 used both hands simultaneously in at least two-thirds of the number of trials; and 3 used the simultaneous method in from one to five trials. The method next in order of frequency was that of reaching first with the right hand for one kitty cat, then with the left hand for the other one, with a short interval between these two reactions. In the Left-handed group, 4 of the 6 subjects used the simultaneous method exclusively; one subject used it in 8 trials and used the R-L method in one trial; and one subject used the simultaneous method in 6 trials and the R-L method in 3 trials. One of the two ambidextrous children used the simultaneous method exclusively in all nine trials. The other child used it in 3 trials, and used the R-L method in 6 trials.

Thus, in situations of this type, when two objects of the same

kind, in proximity to each other, are to be secured under the conditions imposed in this experiment, namely, rapid, spontaneous choice of hand, the young child apparently does not specialize in the use of the hands, using one exclusively to reach for an object and the other to hold it; but the hands function primarily in unison, in the most efficient, convenient manner under the circumstance.

Considerable variation was shown with reference to position assumed by the subject at the basket prior to reaching for and grasping the desired object. Relatively few children in any of the groups maintained consistency of position in all trials. In the Right-handed group, 3 of the 16 subjects assumed the same position in all nine trials, one of these children standing center, and two standing right. In the Left-handed group, one of the 6 subjects consistently stood left in all trials. The average per cent of trials in which each position was assumed by the subjects in each of the three groups is as follows:

GROUP	RIGHT POSITION	LEFT POSITION	CENTER POSITION
Right-handed	38 %	16%	46 %
Left-handed	20.4%	37%	42.6%
Ambidextrous	72 %	6%	22 %

The center or front position was favored more frequently than either the right or left, by both the Right-handed and Left-handed groups, although there was individual variation in this respect in both groups. In the Right-handed group, the right position was favored next in degree of frequency; in the Left-handed group, the left position was next in favor. The two ambidextrous subjects both favored the right position more frequently than either the left or center.

The average per cent of turns to the right and to the left, after the kitty cats had been seized, in relation to position assumed by the subjects at the basket prior to reaching for the kitty cats, is given below:

GROUP	RIGHT POSITION		LEFT POSITION		CENTER POSITION	
	Direction of turn					
	R	L	R	L	R	L
Right-handed	3.6%	96.4%	86.4%	13.6%	40%	60%
Left-handed	9 %	91 %	95 %	5 %	25%	75%
Ambidextrous	—	100 %	100 %	—	25%	75%

Apparently there is an inverse relation between right or left position and direction of orientation, since in all three groups, after the object was secured when the subject stood at the right of the basket, the direction of orientation was almost invariably toward the left; and when the left position was assumed by the subject at the basket, the direction of orientation was primarily to the right. When central position was maintained, the majority of turns made in all three groups was toward the left.

Consistency in direction of turn was shown by 6 children in the Right-handed group and 2 children in the Left-handed group. Two of the right-handed children had stood right in all trials; 3 had stood either right or center; and one had stood right or center in 8 trials, and left in one trial. These six subjects all turned left in the 9 trials. One of the left-handed children stood left in all nine trials, and turned right consistently; the other child stood right or center in 8 trials, and left in one trial, and her direction of turn in all trials was to the left.

Section 2

In this section of test 3, a single object was the stimulus for reaction in a situation imposing rapid, spontaneous choice of hand. The desired object was equally accessible to either hand when approach thereto was in a straight line from the starting point. No provisions were made in the conditions of the experiment, however, to preclude deviations from a straight line approach.

Procedure. One of the kitty cats used in the previous section was utilized in this test series. As in the previous experiment,

the kitty cat was perched in the tin basket, so arranged that the head and upper part of the body projected above the rim of the basket, and was thus visible and easily accessible to the subject. The basket was again placed at one end of the room, about two feet in front of a window, and six feet from the experimenter. The cat was resting against the side of the basket nearest the window, and thus was directly facing the experimenter and subject.

Three daily series of trials were given, each series consisting of 3 trials, making a total of 9 trials for each child. The children were brought into the room in pairs and were given turns alternately in running for the kitty cat. Instructions were similar to those given in the first section, except that the words "that kitty cat" were used in place of "those kitty cats." Again record was taken of (1) the position assumed by the child at the basket—whether in front of the basket, to the right of it, or to the left; (2) the hand with which the cat was grasped; (3) the direction of turn after the cat was secured; (4) whether the cat was transferred to the other hand by the child on returning from the basket to the starting point.

Results. 1. Manual preference. Three types of manipulation were employed by the subjects in this test series, two of them being unimanual in nature, and one bimanual. That is, the cat was grasped with either the right hand, or the left hand, or with both hands simultaneously.

Right-handed group

The average per cent of choices for each of the three types of manipulation evidenced by this group in each daily series of trials, as well as in the total series of nine trials for each subject, is as follows:

MANUAL CHOICE	FIRST DAY	SECOND DAY	THIRD DAY	TOTAL SERIES
Right	56.3%	70.8%	60.4%	62.5%
Left	23 %	16.7%	29.2%	22.9%
Both	20.7%	12.5%	10.4%	14.6%

Although the general tendency of this group was toward more frequent manipulation with the right hand than with the left hand, there was considerable individual variation in degree of choice. While the average per cent of right hand choices in the total series was 62.5%, the range of choice for the right hand was from 100% to zero. Twelve subjects, representing 75% of the group of 16 subjects, showed a marked preference for the right hand, eleven of these children using it in from $66\frac{2}{3}$% to 100% of the total number of trials, and one subject using the right hand in approximately 44% of the trials, and both hands simultaneously in the remaining trials; one child showed no marked favor to either hand; and 3 children favored the left hand to a greater degree than the right, one of these three subjects not using the right hand alone in any trial, but favoring primarily the use of both hands simultaneously.

Consistency in manual choice in all nine trials was shown by 2 subjects only, both of these children using the right hand exclusively. One was a two-year-old and one a three-year-old. However, analysis of the daily series of three trials each indicated that with but one exception, the children in this group were consistent in their manual choice in the three trials of at least one day.

Left-handed group

The average per cent of choices for each of the three types of manipulation evidenced by the group in each of the daily series of trials, as well as in the total series, is as follows:

MANUAL CHOICE	FIRST DAY	SECOND DAY	THIRD DAY	TOTAL SERIES
Right	14.3%	14.3%	14.3%	14.3%
Left	62 %	71.4%	76.2%	70 %
Both	23.7%	14.3%	9.5%	15.7%

The general tendency of this group was toward a pronounced bias for the left hand. Although there was some variability in response, both with respect to the preferential manipulation exhibited by the individual children in the total series of trials,

and in the performance of any given child in successive daily tests, with but one exception the children in this group definitely favored the left hand. While the average per cent of left hand choices was 70%, in the total number of trials, the degree of bias for the left hand ranged from 100% to zero. Five subjects used the left hand in from $66\frac{2}{3}$% to 100% of the total number of trials; one subject used the left hand in 44% of the total number of trials and both hands simultaneously in the remaining trials; and one subject did not use the left hand alone in any of the trials, but used the right hand in eight trials and both hands simultaneously in one. This latter subject was one of the two kindergartners previously referred to.

Consistency in manual choice in the total number of trials was shown by 2 children, both of these using the left hand exclusively. Analysis of the daily series of 3 trials each, indicates, however, that with but one exception the children in this group showed consistency in manual bias on at least one day.

Ambidextrous group

The performances of the three children in this group varied considerably from each other. One child used the left hand consistently in all three trials on each of two days, and used each of the three types of manipulation in one of the trials on one day. Another child used both hands simultaneously in all three trials on each of two days, and used both hands simultaneously in two trials and the left hand in one trial, on one day. The third child in this group consistently favored the right hand in all trials on one day, and on each of the other two days he favored the left hand in two trials and the right hand in one trial. Thus, not only was there variability in the performance of the children with respect to each other, but all of the children varied to some extent in the trials on different days.

2. Preferential manipulation and position. Although the variability in response found in all three handedness groups may be due to individual differences in the nature of the right or left hand drive or urge, suggestive of degrees of manual bias, various environmental factors may contribute to this variability, modifying

to some extent the "native" tendency. One of these factors is the position assumed by the child at the basket—whether he stood directly in front of the basket, at the right, or at the left.

Two facts must be noted with reference to the designation of position assumed by the child as right, left, or center. First, with reference to the center position: as this designation is based entirely on the observation of the experimenter, it is possible that in some instances where a child is termed as having assumed a center position, his position might have been to the right or left, but to so slight an extent that it was impossible to discern by simple observation; nevertheless, the extent may have been sufficient to influence the child's performance, in so far as the positional factor operates in manual choice. Secondly, the assumption of a right or left position at the basket is not a simple two-positional affair, but presents a variety of situations, in that, (1) there are variations in the degree of deviation to the right or left from a straight line approach to the object, and (2) there are variations in the angular incidence of the body in relation to the object grasped. That is to say, a child might assume a position at the front of the basket, somewhat to the right of a straight line approach to the object, yet its body might be in such a position that an imaginary plane drawn through the long axis of the body dividing it into an anterior and posterior section would be at right angles to the straight line approach to the object. In that case, the *left* hand of the child would be nearer the object than the right hand. Or, the child might assume a position to the right of the straight line approach, but turn his body toward the basket and the kitty cat, in which case the *right* hand would be nearer the object than would be the left hand. One subject frequently ran past the right side of the basket, reaching out as he ran with the left hand, which, under this condition, was nearer the kitty cat than was the right hand. Another child would run past the basket at the left, then would made a complete right turn at the rear of the basket though remaining at the same side of the basket, and would then thrust out the left hand, which under these conditions was nearer the desired object, and would grasp the kitty cat with that hand. A third child would some-

times do this when at the right of the basket; that is, he would run past the basket at the right, make a complete left turn, though remaining on the same side of the basket; and would then thrust out the right hand, which was nearer the object, and grasp the kitty cat with it.

Right-handed group

The tendency of the Right-handed group was to favor the position at the right of the basket to a greater extent than either the left or center position; in fact, to a greater extent than both of these positions combined. Of the total of 144 trials, the right position was assumed in 75 trials, or 52% of the total number; the left position in 36 trials, or 25% of the total number; and the center position in 33 trials, representing 23% of the total. With reference to individual choices, 11 subjects, representing 68.75% of the group, favored the right position more frequently than the left, although 2 of these subjects favored the central position more frequently than the right; and 5 subjects favored the left position more frequently than the right.

The average per cent of choices favoring each of the three methods of manipulation in each of the three positions assumed is as follows:

HAND USED	RIGHT POSITION	LEFT POSITION	CENTER POSITION
Right	77.3%	36.1%	57.6%
Left	17.3%	41.7%	15 %
Both	5.4%	22.2%	27.4%

When the position at the right of the basket was assumed, the tendency to use the right hand in reaching for and grasping the kitty cat was pronounced on the part of the majority of the subjects. Of the 13 children who assumed the position at the right of the basket in one or more trials, 8 did not favor the left hand in any trials in this position, six of these eight subjects favoring the right hand exclusively, and two of them using both hands simultaneously in one trial and the right hand in all others; two subjects used the right hand in the majority of the trials in that

position and the left hand in one or two trials; one used the left hand in the majority of the trials and the right hand in but one; and two subjects did not use the right hand at all when standing at the right, but favored either the left hand or the use of both hands simultaneously. The child who used the right hand in but one trial and the left hand in the remaining trials, was the one referred to on a preceding page, who would run past the basket at the right, and as he passed, would reach out with the left hand, which under these conditions was nearer the object, and would grasp the kitty cat with that hand. Nothing was noted in the performance of the other children in this group who occasionally used the left hand when standing at the right, which might account for that preference. One of the two children who had consistently used the right hand in all nine trials to grasp the kitty cat had stood at the right in all trials, and the other child had stood right in seven trials and center in two trials.

When the position at the left was assumed by the children in this group, considerable variation was shown in manual choice. Of the nine children in this group who assumed the left position in one or more trials, four did not use the right hand at all but used either the left hand or both hands simultaneously, two did not use the left hand in any trials but varied between the use of the right hand and both hands simultaneously; two used the right hand in some trials and the left hand in others; and one child used each of the three forms of manipulation in one trial each.

When the position at the center or front was assumed by the children in this group, there was a pronounced tendency toward the use of the right hand in preference to the left on the part of the majority of these subjects. Of the ten children who adopted the center position in one or more trials, seven did not use the left hand in any of the trials, and three used the left hand in one or two trials and the right hand or both hands simultaneously in the remaining trials in this position.

Left-handed group

In the total number of 63 trials made by all subjects in this group, the right position was assumed in 31.7% of the trials;

the left position in 28.6%; and center position in 39.7%. Considerable variability was shown by the children in this group with reference to position assumed at the basket, two of them favoring the right position in the majority of trials, two favoring the left position, and two favoring the center position.

The average per cent of choices favoring each of the three methods of manipulation in each of the three positions, is as follows:

HAND USED	RIGHT POSITION	LEFT POSITION	CENTER POSITION
Right	40%	5.5%	0
Left	55%	94.5%	66.7%
Both	5%	0	33.3%

When the position at the right of the basket was assumed, the performances of the three children who assumed this position varied from each other, although each child was practically consistent in its manual choice in this position. One subject used the right hand in all eight trials made when standing at the right; one child used the left hand in eight trials in this position; and one child used the left hand in three trials and both hands simultaneously in one trial.

When the position at the left of the basket was assumed, little variation in preference was shown, either in the various trials of any given child, or in the performance of the four different children who assumed the left position. Of the eighteen choices made in the left position, seventeen favored the left hand and one the right hand. Thus, as in the Right-handed group, when the position at the basket was on the side corresponding to the habitually preferred hand, that hand was given pronounced preference.

When the center or front position was assumed, the right hand was not used in any of the trials. Four of the children used the left hand only; one child used both hands simultaneously in the one trial made by him in this position; and two children used

either the left hand or both hands simultaneously. This performance, also, is similar to that of the Right-handed group, in that the hand habitually preferred in daily activities was favored to a pronounced extent when the center position was assumed.

Thus, in both the Right-handed and the Left-handed groups, the greatest extent of variability in preferential manipulation was noted when the position at the basket was on the side opposite to that of the "preferred" hand. When the position corresponding to the habitually preferred hand was adopted, or when a center position was assumed, there was a pronounced bias in favor of the "preferred" hand in both groups.

Ambidextrous group

One of the three subjects in this group assumed a position at the left of the basket in all 9 trials; one stood at the right in 5 trials, and at the left in 4 trials; and one stood right in 5 trials, left in 3 trials, and center in one. Thus, in the total number of trials made by this group, the right position was assumed in 10 trials, or 37% of the total; the left position in 16, or 59.3%; and center position in but 1 trial, representing 3.7%.

The average per cent of choices for each type of manipulation in each of the positions was as follows:

RIGHT POSITION			LEFT POSITION		
Hand used					
R	L	B	R	L	B
60%	40%	—	6.2%	43.8%	50%

In the one trial made in center position, both hands were used simultaneously.

3. *Direction of orientation and position at the basket.* The average per cent of turns to the right and to the left, after the kitty cat had been seized, in relation to the position assumed by the subject at the basket prior to seizing the desired object, is as follows:

GROUP	RIGHT POSITION		LEFT POSITION		CENTER POSITION	
	Direction of turn					
	R	L	R	L	R	L
Right-handed	—	100%	97.2%	2.8%	27.3%	72.7%
Left-handed	—	100%	100 %	—	40 %	60 %
Ambidextrous	—	100%	100 %	—	—	—

It will be noted that in all three handedness groups, when a position to the right or to the left of the basket was assumed by the subject prior to reaching for and grasping the desired object, after it was secured orientation of the subject was almost invariably in the direction opposite to that of the position maintained, regardless of the manual choice exhibited in the trials. In all but one trial in a total of 175, orientation was inversely related to position assumed. This one exception was noted in the performance of a right-handed child who stood at the left in 8 trials, in seven of which he turned right after grasping the kitty cat, and in one he turned left. No factor was observed which might have occasioned this variation.

When the center or frontal position was maintained, variation in direction of turn was observed in both the Right-handed and the Left-handed groups with reference to the performance of different children, and also with reference to the various trials of specific subjects. In the Right-handed group, 6 of the 10 children who stood center in one or more trials favored the left turn only; 2 favored the right turn only; and 2 varied between the right and the left. In the Left-handed group, one child turned right in 7 trials and left in 2 trials when standing center, and one turned left in 7 trials and right in one trial. Of the five children who stood center in one or two trials, three turned left, one turned right, and one varied the direction of turn in different trials. The one ambidextrous child who stood center in one trial turned left.

Section 3

As in section 2, a single object was the stimulus for reaction. The effort was made to eliminate, in so far as possible, the effect

of position as a factor in manual choice, by placing the object in such a way that deviations to right or left from a straight line approach from the starting point would be precluded, thus rendering the object equally accessible to either hand.

Procedure. One of the kitty cats used in section 1 was utilized in this series. The kitty cat was placed on a bench, approximately 4 feet long, 1 foot wide, and 1 foot 6 inches high. This bench was placed against the wall, with the kitty cat in the center of it, resting against the wall.

One series of 3 trials was given to each child. These trials could not be continued over a three-day period as was done in the preceding section, owing to the fact that the time was approaching for the close of the Institute during the summer months. The children were again brought into the room in pairs, and, as in the two previous sections, were given turns alternately in running for the kitty cat. Instructions were similar to those given in the first section, except that the words "that kitty cat" were used in place of "those kitty cats." Record was taken of (1) the hand with which the cat was grasped, and (2) the direction in which the subject turned after the desired object was secured. In this test series, as in section 2, three types of manipulation were employed, namely, the use of the right hand, the left hand, or both hands simultaneously reaching for and grasping the object.

Results. 1. Manual preference.—

Right-handed group

The average per cent of choices for each of the three types of manipulation employed by this group in this three-trial series is as follows:

Right hand: 58.3% *Left hand:* 27% *Both hands:* 14.7%

The general tendency of the children in this group was toward more frequent manipulation with the right hand than with the left, or with both hands functioning simultaneously, although there was some individual variation. Consistency in type of

manipulation in the three trials was shown by 11 children, 7 of them consistently using the right hand, 2 consistently using the left hand, and 2 using both hands simultaneously in all trials.

The results obtained in this three trial series were compared with those found in each of the daily three-trial series in section 2, with respect to degree of preference for the right hand, and consistency of manual preference in a three-trial series of choices. The number of children who consistently favored any one of the three forms of manipulation in the three consecutive trials of each daily series in section 2, and in the three trials of section 3, respectively, is as follows:

DAILY SERIES OF 3 TRIALS EACH	SECTION 2			SECTION 3
	1	2	3	
Form of manipulation:				
Right hand	5	9	6	7
Left hand	2	0	2	2
Both hands simultaneously	2	1	0	2

It will be noted that, with respect to the number of children who consistently used a given form of manipulation in the three consecutive trials of a one-day series of choices, the results found in section 3 did not vary from those found in any one of the three daily three-trial series in section 2 to any greater extent than did these daily series vary from each other. In fact, as far as consistency in right hand preference was concerned, the degree of difference between the second and first daily series, and between the second and third daily series, respectively, in section 2, was greater in both cases than that between section 3 and any one of the three daily series in section 2. It will also be noted that the average per cent of choices made by this group for the right hand and for the left hand respectively in section 3 does not vary from the average per cent of choices for each of these forms of manipulation in the first daily series or in the third daily series of section 2 (as shown on page 35), to any greater extent than do the average per cents of such choices in the first and third series vary from

each other; and the extent of variation in average per cent of choices for the right hand and for the left hand between section 3 and the first or the third daily series of section 2 is much less than the variation in this respect between the second daily series and the first and third respectively of section 2.

Left-handed group

The average per cent of choices for each of the three types of manipulation employed by this group in this three-trial series is as follows:

Left-hand: 77.8% *Right-hand:* 22.2% *Both:* 0

The general tendency of the children in this group was toward more frequent preference for the left hand than for the right. There was some individual variation with respect to degree of bias for the "preferred" hand, as 2 of the children used the left hand in all three trials, and the remaining 4 children used the left hand in two trials and the right hand in one trial. No significant difference was noted between the results in this three-trial series and any one of the three daily series in section 2.

Ambidextrous group

The three children in this group favored primarily the use of both hands simultaneously in the trials of section 3. Two of these subjects used this method exclusively, and the third child used it in two trials, and used the right hand alone in one trial.

2. Orientation and manual choice.—

Right-handed group

The average per cent of turns to the right and to the left, after the kitty cat had been secured, in relation to each of the three types of manipulation employed, is as follows:

RIGHT HAND USED		LEFT HAND USED		BOTH HANDS USED	
Direction of turn					
R	L	R	L	R	L
32.2%	67.8%	23%	77%	57%	43%

Although the average per cent of turns to the right and to the left indicates that the tendency of the group was toward a greater degree of preference for the left turn following the use of the right hand as well as the use of the left hand, nevertheless there was considerable individual variation. Of the 7 subjects who had used the right hand consistently in the 3 trials, 3 of these turned to the left in all trials, 1 turned to the right, and 3 varied the direction of turn in different trials. Both of the subjects who used the left hand in all 3 trials, turned left following seizure of the kitty cat. One of the 2 subjects who used both hands simultaneously in all trials turned right in all trials, and one varied her direction of turn in different trials. Of the 5 subjects in this group who showed variation in manual choice, 2 consistently evidenced inverse relationship between manual choice and orientation, turning right after the left hand had been used, and left after the right hand had been used; 2 consistently turned left, regardless of the hand used; and one subject turned left in 2 trials, in one of which the right hand was used, and one the left, and turned right in one trial following the use of the left hand. Thus, it appears that in this group no invariable relationship was exhibited between manual choice and direction of turn following seizure of the desired object, as 5 subjects consistently exhibited inverse relationship between manual choice and orientation; 3 children exhibited direct relationship, turning right following the use of the right hand, and left following the use of the left hand; and 7 children varied, showing a direct relationship in one or more trails, and inverse relationship in others. It may be that some other factor, such as final foot position just prior to reaching for the kitty cat, conditions the direction of turn. No consistent relationship was exhibited between direction of turn and manual "types", as 7 of these right-handed children turned left in all trials; 2 turned right in all trials, and 7 varied their direction of turn in different trials.

Left-handed group

The average per cent of right and left turns following each of the types of manual choice exhibited by this group, is as follows:

RIGHT HAND USED		LEFT HAND USED	
Direction of turn			
R	L	R	L
—	100%	64.3%	35.7%

The total number of trials made in this group is too small to warrant any generalization. There were but 4 right-hand choices made, all of these being followed by the left turn. When the left hand was used, there was some variation, as 3 children turned to the right, one child turned left, and 2 children varied in direction of turn in different trials. In this group as in the Right-handed group, no constant relationship between direction of turn and manual choice was apparent, as 3 children exhibited inverse relationship between manual choice and direction of turn, and 3 children varied, showing inverse relationship in one or more trials, and direct relationship in the remainder. No consistent relationship was shown between direction of turn and manual "types", as 1 of these left-handed children turned right in all trials; one turned left in all trials; and the remaining 4 children varied in direction of turn.

Ambidextrous group

Little opportunity was afforded to study the relation of turn to manual choice in this group, as there was only one trial in which the right hand was used alone, and none in which the left hand was used alone. In this one trial, orientation was to the left. Where both hands were used simultaneously, right turns predominated to a marked degree. One child turned right in all trials, and two children turned right in two trials and left in one trial.

Relatively little variation in type of performance was shown by any of the children in the three sections of this test. That is to say, where a child had exhibited a pronounced degree of preference for the right hand, or for the left hand, in any given section, the tendency was, on the whole, toward the same type of per-

formance in the other sections. Although variations did occur, as for example, in the performance of a few subjects in the three-trial series of section 3 as compared with section 2; these variations were no different in kind or degree than those found in section 2 between the various daily three-trial series.

There were but few children in any of the three handedness groups who maintained consistency in direction of orientation throughout all trials of the three sections of test 3. In the Right-handed group, 4 subjects, representing 25% of the group turned to the left in the total number of trials in all three sections of this test, namely, twenty-one trials; and in the Left-handed group, one child consistently turned right in all trials. The remaining children in these two groups varied in direction of turn in different trials, some favoring the right turn more frequently, some favoring the left turn primarily; however, in both groups the majority of children turned more frequently to the left. No factor was noted which might explain the marked preference for the left turn.

A comparison of the performance of each subject in the various tests

A comparison was made of the performance of each subject in tests 1 and 2, and in section 2 of test 3, respectively, for the purpose of ascertaining the consistency of manual bias exhibited by each child in the various tests. Sections 1 and 3 respectively of test 3, the picking-up-toy test, were not included in this comparison, for the following reasons: in section 1, the form of manipulation primarily favored by all of the subjects was that of reaching with both hands simultaneously, grasping an object in each hand; in section 3, the number of trials given were too few to warrant generalizations as to preferential handedness.

Right-handed group

The per cent of choices made in favor of the right hand by each subject in tests 1 and 2, and in section 2 of test 3, respectively, is shown in table 1. Of those subjects who did not use the right hand exclusively in a given test, some performed the remaining

trials by the use of both hands simultaneously, some used the left hand alone for all trials in which the right hand was not used, and some used both of these methods. A single asterisk placed beside the per cent of right hand choices in table 1 indicates that the remaining trials were performed by both hands functioning simultaneously; a double asterisk indicates that part of the remaining trials were performed by the left hand alone and part by both

TABLE 1

Right-handed group

Per cent of choices favoring the *right* hand in the respective tests

SUBJECT	AGE		TEST 1: MARBLE-BOARD	TEST 2: FORMBOARD		TEST 3: PICKING-UP-TOY
				Right side	Left side	
B	2′	6″	97%	100%	0	66.7%**
C	2′	7″	62%	100%	0	100 %
D	2′	11″	100%	100%	45%	78 %
F	3′	11″	75%	75%	25%	11 %
G	3′	9″	90%	75%	5%	90 %
H	3′	10″	100%	100%	75%	44.4%*
I	3′	11″	92%	100%	15%	100 %
J	3′	4″	100%	100%	45%	66.7%*
K	3′	11″	100%	100%	5%	44.4%**
N	4′	5″	50%	100%	0	0**
O	4′	5″	100%	100%	100%	78 %
P	4′	9″	100%	100%	70%	66.7%
R	5′		100%	100%	100%	22 %**
S	5′	2″	50%	100%	75%	78 %
T	5′	3″	85%	75%	50%	90 %*
U	5′	4″	100%	100%	10%	66.7%**

hands simultaneously. Where no asterisk appears, the trials in which the right hand was not used alone were performed by the left hand, functioning alone.

Analysis of table 1 indicates that while none of the children in this group consistently used their habitually preferred right hand, alone, in all trials of all three tests, there were a few who showed a pronounced preference for the right hand in all tests; and the

majority of this group showed a marked preference for the right hand in tests one and three respectively, and in manipulating the forms at the right of the formboard in test two.

Three subjects, H, O and P, representing 18.75% of the group, showed a definite bias for the right hand in all three tests. These children used the right hand exclusively in manipulating the one-hundred marbles in test 1, and in manipulating the forms at the right of the formboard in test 2. In manipulating the forms at the left of the board, subject O used the right hand exclusively, and subjects H and P used the right hand in the majority of trials. In section 2 of the Picking-up-toy test, while none of these subjects used the right hand exclusively in all trials in the total three-day series, each one used the right hand exclusively in the three trials of at least one daily series; and all three used the right hand to a much greater extent than the left. In fact, subject H did not use the left hand alone in any of the trials in section 2 of test 3.

Eight subjects B, C, D, G, I, J, T and U, representing 50% of the group, showed a pronounced bias for the right hand in all tests except in that section of test 2 in which the forms at the left of the formboard were manipulated. Five of these subjects, B, C, G, I and U, favored the left hand to a pronounced degree in that section of the formboard test; while three of the subjects, D, J and T, did not favor either hand to any marked extent.

One subject, K, used the right hand exclusively in the first test, and in manipulating the forms at the right in the second test; however, in manipulating the forms at the left in that test he strongly favored the left hand; and in section 2 of test 3, he showed no marked preference for either hand.

Three subjects, F, N and R, representing 18.75% of the group, showed a marked preference for the left hand in section 2 of test 3, a section in which the twelve children named above favored the right hand primarily or exclusively. Subject N did not use the right hand alone in any trials in this section. In the manipulation of the forms at the right of the board, in test 2, these subjects all favored the right hand primarily; however, in test 1 and in the manipulation of the forms at the left of the board in test 2, they

differed in performance. In test 1, subjects F and R primarily favored the right hand, while subject N showed no preference for either hand. In manipulating the forms at the left of the board in test 2, subjects F and N each favored the left hand, whereas subject R used the right hand exclusively.

Subject S showed a marked favor for the use of the right hand in manipulating the forms at the left as well as those at the right in test 2, and in section 2 of test 3; however, in test 1 this subject showed no marked preference for either hand, using each hand in manipulating 50% of the marbles.

The series of ten daily observations of uncontrolled activities of these children, reported by the experimenter in the last section of this paper, gave no evidence of preferential use of the left hand (that is, in activities other than the picking up of objects under conditions favoring the use of the left hand) except in the case of subject F. This subject occasionally picked up the tiny boards containing colored pins from a box with the right hand, and holding the board in the right hand, he would remove the tiny pins from it with the left hand and place them in the beaver board with that hand. Subject S had used his left hand primarily the year previous to these experiments; however, according to the report of his parents, and observations of daily activities made by the experimenter, he was, at the time of this study, definitely right-handed in his habits.

Left-handed group

The per cent of choices made in favor of the left hand by each child in tests 1 and 2 respectively, and in section 2 of test 3, is shown in table 2. A single asterisk placed above the per cent of left hand choices in this table indicates that the remaining trials were performed by both hands functioning simultaneously; a double asterisk indicates that part of the remaining trials were performed by the right hand alone, and part by both hands simultaneously. Where no asterisk appears, and the left hand has not been used exclusively in 100% of the trials, the right hand was used alone in the remaining trials.

Analysis of table 2 indicates that, while none of the subjects in

this group used the left hand exclusively in all tests, the tendency of the majority was toward a pronounced preference for the left hand in all tests except that section of test 2 in which forms lying at the right of the board were manipulated. One subject, Ee, showed a strong bias for the left hand in all tests, including that section of test 2 in which the objects of manipulation were lying at the right of the board. Three subjects, Dd, Ff and Gg, representing 50 per cent of the group, showed a marked favor for the use of the left hand in all tests except in manipulating the forms at the right of the board in test 2, one of these subjects, Dd, using the right hand primarily in that section, and subjects Ff and Gg

TABLE 2

Left-handed group

Per cent of choices favoring the *left* hand in the respective tests

SUBJECT	AGE		TEST 1: MARBLE-BOARD	TEST 2: FORMBOARD		TEST 3: PICKING-UP-TOY
				Left side	Right side	
Dd	3′	10″	80%	100%	30%	100 %
Ee	4′	3″	85%	100%	70%	100 %
Ff	5′	2″	92%	100%	45%	44.4%*
Gg	5′	4″	92%	100%	45%	90 %*
Hh	6′	2″	6%	100%	20%	10 %
Ii	6′	5″	55%	100%	30%	90 %

showing no marked favor to either hand. Subject Ii showed a marked preference for the left hand in test 3, and in the manipulation of the forms at the left in test 2; however, she used the right hand to a marked degree in manipulating the forms at the right in test 2; and in test 1, she showed no marked favor to either hand. Subject Hh exhibited strong right hand preference in all tests except in the manipulation of the forms lying at the left of the formboard in test 2. In that section he used the left hand exclusively. This subject was reported by his parents as being left-handed. He had been attending kindergarten for a year prior to these experiments, and during that period had been participating in games with other children of his age.

Ambidextrous group

The per cent of choices favoring the hand used in the majority of trials in each of the three tests, is given below for each of the three subjects in this group:

SUBJECT	TEST 1 (MARBLEBOARD)	TEST 2 (FORMBOARD)		TEST 3 (PICKING-UP-TOY) SECTION 2
		Right side	Left side	
Cc	R 55%	R 100%	L 90%	R 56%
Jj	L 100%	R 60%	L 95%	B 90%
Kk	L 70%	R 90%	L 100%	L 78%

All three of these subjects favored the "convenient" hand, in test 2; although when the "convenient" hand was the left hand, the degree of bias was very pronounced on the part of all three subjects, whereas when the "convenient" hand was the right hand, that is, when the forms at the right of the board were manipulated, there was some variation in degree of bias shown by the three subjects. Subject Cc, who used the right hand exclusively in manipulating the forms at the right in test 2, and who used the left hand somewhat less than the other two subjects in manipulating the forms at the left in that test, favored the right hand slightly more than the left in tests 1 and 3 respectively. Subjects Jj and Kk both favored the left hand primarily in test 1, and in test 3 subject Kk favored the left hand to a marked degree while subject Jj used both hands simultaneously in the majority of trials.

An evaluation of the specific tests as suggested means of diagnosing "native" handedness

The results obtained in tests 1 and 2, and section 2 of test 3, were studied for the purpose of evaluating these tests as means of diagnosing so-called "native" handedness. As previously stated, the criterion of "native" handedness was the report of the parent as to the hand used in daily activities. This study included only the performances of the 13 children in the Right-handed group, 6 in the Left-handed group, and 2 in the Ambidextrous group, who

had completed tests 1 and 2, and section 2 of test 3. Thus, the performances of subjects B, C, D in the Right-handed group, subject Aa in the Left-handed group, and subject Cc in the Ambidextrous group, were not included in this analysis because each of them failed to complete one or more of the tests. For example, subjects B, C and Aa completed only one of the 4 trials in the

TABLE 3

A comparison of the degree of choice for the "preferred" hand manifested in each test

	TEST 1	TEST 2		TEST 3 SECTION 2
		Right side	Left side	
Right-handed group—13 subjects				
Number of subjects making 100% *right* hand choices	7	10	2	1
Number of subjects making 66.7% or more, *right* hand choices	11	13	5	8
Average per cent of *right* hand choices made by group	87.6%	94.2%	44.2%	58.1%
Average deviation	14.4%	8.9%	31.6%	25.7%
Left-handed group—6 subjects				
Number of subjects making 100% *left* hand choices	0	0	6	2
Number of subjects making 66.7% or more, *left* hand choices	4	1	6	4
Average per cent of *left* hand choices made by group	68.3%	40 %	100%	70.3%
Average deviation	25.2%	13.3%	0	32.5%

Formboard test; and subjects C, D, Aa and Cc did not complete the Marble Board Test.

The results obtained in sections 1 and 3, respectively, of the Picking-up-toy test are not included in this comparative study for the reason that, in section 1, the form of manipulation primarily favored was that of simultaneously reaching and grasping with both hands, each hand seizing one of the two desired objects; and in section 3, the number of trials given were too few to warrant generalizations being drawn therefrom.

Table 3 shows the following for each test: (1) the number of children in the Right-handed and in the Left-handed group, respectively, who showed consistent preference for the habitually "preferred" hand; (2) the number of children in each group who showed preference for the "preferred" hand in at least $66\frac{2}{3}\%$ of the total number of choices in a given test; (3) the average per cent of choices made by each group for the "preferred" hand; (4) the average deviation.

Analysis of the results shown in the Marble Board test, and those shown in the manipulation of the right and left sides, respectively, of the Formboard test, indicates that in both the Right-handed and the Left-handed groups, less individual variation and a higher degree of manual bias for the "preferred" hand is shown in the manipulation of the forms lying at the side of the Formboard corresponding to the "preferred" hand than is shown in test 1, or in the manipulation of the forms lying at the side of the Formboard opposite to that corresponding to the "preferred" hand—termed the "non-preferred" side—in test 2. In fact, there is uniformity of preferential manipulation of the forms at the "preferred" side of the board; for in the Right-handed group all of the children used the right hand to a pronounced degree, although but 10 of the 13 subjects used that hand exclusively; and in the Left-handed group, all six of the subjects favored the left hand exclusively in manipulating the forms at the left. The Marble Board test ranks second with respect to degree of manual bias for the "preferred" hand, as shown by the average per cent of choices for that hand made by each group, as well as by the number of children in each group who favored the "preferred" hand exclusively, or at least primarily. The lowest degree of manual bias for the "preferred" hand was shown by each group in manipulating the forms lying on the side of the Formboard opposite the habitually preferred hand. It will be noted that in the Left-handed group, the average deviation in the Marble Board test is somewhat higher than in that section of the Formboard in which the forms lying at the "non-preferred" right side were manipulated. Analysis of individual performances indicates that in the Marble Board test, subject Hh, who,

as before stated, had been attending kindergarten for a year prior to taking these tests, used the right hand in manipulating 94% of the marbles, while the remaining five children in this group strongly favored the left hand in that test. The performance of the two ambidextrous children was similar to that of the majority of the children in the Left-handed group, as both of these subjects showed a pronounced preference for the left hand in the first test, as well as in manipulating the forms at the left in the second test; whereas in the manipulation of the forms at the right in the second test, the right hand was favored primarily though not exclusively.

Thus, it appears that the factor of convenience plays an important part in the preferential manipulation of children in tests of the type given, and under the conditions presented. When objects were conveniently located with reference to the "preferred" hand, the tendency to use that hand was pronounced on the part of all of the children in both the Right-handed and Left-handed groups. When objects were equally accessible to either hand, the tendency toward the use of the "preferred" hand was likewise pronounced on the part of the majority of the children in both groups, although there were some individual variations. When objects were conveniently located with reference to the "non-preferred" hand but inconveniently located with reference to the "preferred" hand, considerable variation in degree of bias for the "preferred" hand was shown on the part of the subjects in both groups, a minority only favoring the "preferred" hand to a pronounced degree; as the remaining children varied from exclusive use of the "non-preferred" but convenient hand, to approximately equal degrees of choice for each hand.

If we assume that a test becomes an adequate measure of so-called "native" handedness in so far as the results of such a test agree with the "facts of the case" (as determined by reports of the parents as to the preferential manipulation exhibited by the child in daily activities); then, on the basis of the above data, we may assume that a test of the Formboard type, in which a convenience is offered to the use of the "preferred" hand, is an adequate test of "native" handedness, since the results of the Formboard test on the "preferred" side of the board (in which a

convenience is offered to the use of the preferred hand) show marked agreement with reported daily preferential handedness. And, if the degree of preference manifested for the preferred hand in a given test, ranging from 100% to zero, is indicative of *degree* of "native bias", then on the basis of the above data, a test such as the Formboard under conditions offering an *inconvenience* to the use of the preferred hand may be considered an adequate test of the "degree" of manual bias.

However, in as much as the purpose of a test of "native" handedness, and of degree of manual bias, is to ascertain these facts in cases where they are not known, rather than to confirm them according to some already accepted criterion, neither of these facts could be ascertained by a test which involved *one* of the situations only, that is, convenience *or* inconvenience to the use of the preferred hand. For example, if a group of children regarding whose manual bias nothing is known were to manipulate forms lying at the left of the board only, among the group who used the left hand consistently, or to a pronounced degree, would be, presumably, practically all of the children who were "natively" left-handed, as well as those children who, in daily activities, were primarily right-handed, but who used the left hand in activities of certain types when convenience dictated; that is to say, those children who were natively right-handed, but to a lesser degree than many others. And, in order to determine which of those children who used the left hand for the manipulation of forms lying at the left of the board were "natively" left-handed, and which were right-handed children of relatively low degree of bias, it would be necessary to introduce the opposite form of test, wherein the forms were placed at the right of the board, thus offering an inconvenience to the native left-handers, and a convenience to the right-handers. Then would be introduced another factor, precluding the determination of absolute types; for, in as much as among the left-handers as well as the right-handers, there were found some individuals who favored the "preferred" hand despite the inconvenience imposed, and others who favored the "non-preferred" but convenient hand; there would then result a group of children who favored the

"convenient" hand, using the right hand when objects were conveniently located with reference to it, using the left hand when that hand was so favored: a group of children among whom there were some who, in daily activities such as painting, drawing, and cutting with a scissor, consistently used the right hand; some who, in these activities, consistently used the left hand; and some who, in these activities, used the hands interchangeably. The assumption of *degrees* of manual bias, ranging from a pronounced degree of preference for either the right or the left hand, to an ambidextrous state where neither hand is favored, seems to fit the results found in all tests given in this study. And, a test of the type of the Formboard, given under conditions used in this study, wherein a number of objects were conveniently located with reference to the right hand, and the same number conveniently located with reference to the left hand (thus offering an inconvenience to whichever was the "preferred" hand in the manipulation of half of the forms), provides a method of ascertaining these *degrees* of manual bias, rather than ascertaining a division into definite "types".

In the Marble Board test, in which equal opportunity was offered for the use of either hand, while the number of children in each group who showed pronounced favor to the "preferred" hand was not quite as large as the number who showed a pronounced bias in manipulating the forms on the "preferred" side of the board in the Formboard test, nevertheless it was considerably larger than the number who showed a pronounced bias in manipulating the forms on the "non-preferred" side of the board in that test. It might be that the nature of manual choice under conditions offering equal opportunity for the use of either hand is diagnostically more significant in ascertaining manual bias than is the nature of choice when objects are conveniently located with reference to one hand, but inconveniently located with reference to the other, in as much as factors of convenience apparently predispose to the use of the "convenient" hand—practically exclusively when the convenient hand is also the preferred hand, and to varying extent when the convenient hand is the non-preferred hand. So that, in so far as it is possible to divide individuals into "native" right-handers, left-handers or ambidexters, the

Marble Board, or the Peg Board, or a test of similar type, given under conditions affording equal opportunity for the use of either hand, may be adequate. However, the author inclines to the view that such a test determines *trends* rather than definite types.

The average per cent of right hand choices made by the Right-handed group in the Picking-up-toy test was considerably less than in the Marble Board test, or in the manipulation of the forms at the right in the Formboard test; but was greater than in the manipulation of the forms at the left in the Formboard. In the Left-handed group, the average per cent of left hand choices made in the Picking-up-toy test was greater than in the manipulation of the forms at the right of the Formboard, and slightly greater than in the Marble Board test; but was considerably less than in the manipulation of the forms at the left in the Formboard.

Among the environmental factors noted which may have affected manual bias in this test was that of variation in position. According to the analysis made in section 2 of Test 3, of manual choice in relation to the position assumed by the child at the basket prior to reaching for and grasping the desired object, it seemed that, when the position assumed by the children in both the Right-handed and the Left-handed groups was at the side of the basket corresponding to the habitually preferred hand, there was a pronounced preference on the part of the majority of the children toward the use of that hand; when the position assumed at the basket was center, the preference for the "preferred" hand was likewise pronounced, but to a lesser degree than when convenience favored the preferred hand; and, when the position assumed by the child was at the side of the basket opposite to that corresponding to the preferred hand, there was a decrease in average per cent of choices for the preferred hand in both groups, neither hand being definitely favored. Individuals showed considerable variation, some consistently favoring the "preferred" hand though they stood in the "non-preferred" position, some favoring the non-preferred but convenient hand in that position, and some showing no definite preference for either hand. Thus, this test apparently confirms the results found in the Form-

board test and in the Marble Board test, namely: that, under conditions offering a convenience to the use of the preferred hand, there was a pronounced tendency toward the use of the preferred hand on the part of all of the children in both the Right-handed and the Left-handed groups; that under conditions offering equal opportunities for the use of either hand, the preferred hand was definitely favored by the majority of children in both groups; and that, under conditions offering an inconvenience to the use of the preferred hand, there was considerable variation in degree of manual bias for the habitually preferred hand.

While the results in these three positions assumed in section 2 of the Picking-up-toy test approximate the results in the Marble Board test and the Formboard test, where conditions of convenience are relatively the same, nevertheless the degree of manual bias shown in these three positions of section 2 of test 3 vary somewhat from the degree of bias shown in the Marble Board and the Formboard tests. This may be accounted for to some extent by the fact that in the Picking-up-toy test there were many environmental factors which may affect preferential manipulation which were not present in the Marble Board and Formboard tests. In the first place, in the latter named tests, the objects of manipulation were definitely located in *one* of the three following positions: (1) center, thus being equally accessible to either hand, (2) at the right, or (3) at the left. In section 2 of the Picking-up-toy test, the child himself assumed a position, (1) center, (2) to the right, (3) to the left, in relation to the basket and the desired object. However, as previously stated, the assumption by the child of a right or left position is not a two-positional affair, but may vary in, (1) degree of deviation to the right or left from a straight line approach to the object, and in (2) the angular incidence of the body in relation to the object grasped. Also, with reference to central position assumed by the child, as this designation is based entirely on the observation of the experimenter, it is possible that in some instances where a child is termed as having assumed a central position, his position might have been to the right or left, but to so slight an extent that it was impossible to discern by simple observation, though perhaps sufficient to influence the

child's performance, in so far as the positional factor operates in manual choice. Another factor to be considered in comparing the degree of preference for the "preferred" hand in the three positions in section 2 of the Picking-up-toy test with the degrees of bias exhibited in the Marble Board and the Formboard tests, is the fact that the object manipulated in the Picking-up-toy test was of a size which permitted the use of both hands simultaneously in seizing it, whereas the objects used in the Formboard and Marble Board tests were small, and readily grasped by one hand only. Thus, the possibility of three types of manipulation in the Picking-up-toy test reduced the per cent of right hand choices, as well as of left hand choices.

It seems, then, that a test of preferential manipulation in a situation involving rapid, spontaneous choice of hand, under conditions provided in this experiment, does not prove as adequate a test of so-called "native" handedness as does the Marble Board test, wherein equal opportunities were offered for the use of either hand by virtue of the position of the objects to be manipulated rather than by virtue of the position assumed by the child after running toward the object. It may be that environmental factors, such as position assumed by the child at the basket, or perhaps the final foot position of the subject just prior to reaching for and seizing the object desired, influences manual choice. It may also be that this specific activity is too closely related to those daily activites, like picking up an object which has dropped to the floor, picking up desired objects from the table, and so on—in which many children have formed the habit of using either hand, depending upon convenience and other environmental conditions—to warrant the use of a test of this type as diagnostic of so-called "native" handedness.

Summary of tests of handedness. In a series of manual tests given to a group of pre-school children for the purpose of ascertaining the preferential manipulation in motor activities of various types given under varying conditions, the following significant responses were noted:

1. Variability in the type of manipulation employed by the different subjects was shown in all three tests. In the Marble

Board test, while the method favored by the majority of children was unimanual, one hand picking and placing the marbles throughout the test, this method was varied by some of the subjects with one or more forms of the bimanual method. Bimanual manipulation assumed four forms in this test, in two of which the function of the two hands was the same in kind, and in two, the function of the two hands differed.

In the Formboard test, the method of manipulation was primarily unimanual, although occasionally a subject adopted a bimanual method of manipulation, one hand picking the form and passing it to the other hand to place.

In the section of the Picking-up-toy test in which 2 objects were employed, the method of manipulation was almost exclusively bimanual, each hand grasping an object simultaneously with the other. In the sections of this test in which one object was the stimulus for response, unimanual and bimanual methods of manipulation were employed, that is, the desired object was grasped by either the right hand or the left hand, or by both hands simultaneously.

2. The factor of convenience apparently plays an important part in the manual choice of young children in activities of certain types. In the Marble Board test, in which the objects of manipulation were equally accessible to either hand, a pronounced preference for the hand habitually used in daily activities, called the "preferred" hand, was noted on the part of the majority of the children in the Right-handed and the Left-handed groups. The two ambidextrous children who completed this test showed a marked left hand bias therein. Degrees of bias for the "preferred" hand ranged, in the Right-handed group, from the exclusive use of the right hand in manipulating all of the marbles, to a type of performance in which neither hand was shown any marked preference. Fifty per cent of the children in this group used their right hand exclusively. In the Left-handed group, degrees of bias ranged from the almost exclusive use of the left hand on the part of one subject, to the use of that hand in but few choices on the part of another subject.

In the Formboard test, when objects were conveniently placed

with reference to the "preferred" hand, a definite bias for that hand was shown by all of the children in the Right-handed and in the Left-handed groups. Consistency of use of the "preferred" hand in the manipulation of all of the forms in all trials of this test was shown by all of the children in the Left-handed group, and by approximately 84% of the children in the Right-handed group. Thus, under conditions offering a convenience to the use of the "preferred" hand, little evidence of degrees of bias was manifested.

When, however, objects were so placed in the Formboard test, as to offer an inconvenience to the use of the "preferred" hand but a convenience to the use of the "non-preferred" hand, variability in degree of preference for the "preferred" hand was evident in both the Right-handed and the Left-handed groups. In the Right-handed group, the range of preference for the right hand, despite the inconvenience offered, was from 100% to zero; in the Left-handed group, the range of preference for the left hand was from 70% to 30%. The children tended to fall into three groups, as follows: (1) those who, despite the inconvenience offered to the use of the "preferred" hand, nevertheless showed a pronounced tendency toward the use of that hand; (2) those who favored to a pronounced degree the "convenient" but "non-preferred" hand; (3) those who showed no marked degree of preference for either hand. In both the Right-handed and the Left-handed groups, division (2) was the largest.

Consistency in manual choice in manipulating the forms at the "non-preferred" side of the formboard—that is, the side opposite the hand habitually used in daily activities—in all four trials of this test was noted in the performance of 5 right-handed children, representing approximately 30% of the group. Three of these children used the right hand exclusively and two used the left hand exclusively, in manipulating the forms at the left in all trials. None of the left-handed children exhibited consistency in manual choice in all trials. When trials were considered separately, many children in each handedness group consistently favored a given hand in manipulating the five forms on the "non-preferred" side in a given trial.

The three ambidextrous children who completed this test all

favored the left hand to a marked degree in manipulating the forms at the left. In manipulating the forms at the right, all three favored the right hand primarily, although to varying degrees, ranging from 100% to 60%. Thus, the children in the ambidextrous group favored the hand which was more conveniently located with reference to the desired object to a greater extent than the hand not so favorably located; although, when the left hand was the convenient hand, the preference for it was marked to approximately the same extent by all of the children, whereas when the right hand was the convenient hand, there was some difference in degree of preference for it.

Various environmental factors were noted, in the Formboard test as well as in the Marble Board test, which may have influenced manual choice in specific cases, although none of these factors was found to invariably do so.

Only one of the five children in the two-year age group manipulated all of the marbles in the Marble Board test; and one manipulated half of the marbles. These two subjects both favored the right hand practically exclusively. The remaining three two-year olds apparently regarded the marbles as objects to roll, or pick up and let fall through the fingers, an activity in which both hands functioned. In the pegboard test, which was given to all of the two-year-olds as a substitute for the marble board test, the three right-handed children manifested a marked preference for the use of the right hand, and consistently favored this hand in three successive daily tests. The one ambidextrous child and the one left-handed child in this group varied in their manual bias on different days.

In the Picking-up-toy test, in which situations were imposed calling for rapid, spontaneous choice of hand, when two similar adjacent objects were to be secured, no preference was shown to either hand with reference to type of function, in any of the three handedness groups; nor was either hand favored to any extent in point of time as the method of manipulation primarily employed by practically all of the children was that of reaching for and grasping an object with each hand simultaneously. Thus, in situations where two objects of the same type, in proxim-

ity to each other, and equally accessible to either hand are to be secured, the young child apparently does not specialize in the use of the hands, using one exclusively to reach for the object, and the other to hold it; but the hands function primarily in unison, in the most efficient, convenient manner under the circumstance.

When a single object was to be secured in this test under conditions calling for rapid, spontaneous choice of hand, and where a straight line approach to the object from the starting point was rendered feasible, though not exclusive, the tendency toward the use of the "preferred" hand was pronounced on the part of the majority of the children in both the Right-handed and Left-handed groups, although there was individual variation, some children in each group manifesting a pronounced bias for the "non-preferred" hand under these conditions. Considerable variation was shown in degree of manual bias for the "preferred" hand in repeated trials, in both groups, as the use of the "preferred" hand in the total series of trials given over the three day period ranged from 100% to zero. Although comparatively few children in any of the groups were consistent in the use of a given hand in the total number of trials given over the three-day period, when each of the daily series was considered separately, it was noted that on each day the majority of the subjects were consistent in their manual choice in the three trials.

Among the factors noted which might have influenced manual choice in this test was that of the position assumed by the child with reference to the object, after running from the starting point. Considerable variation was noted in position assumed by the subjects at the basket, when reaching for and grasping the kitty cat, not only with reference to a center, right, or left position, but also with reference to the degree of deviation to the right or left, and the angular incidence of the body in relation to the object grasped. Analysis of preferential manipulation exhibited in the three observable positions, right, left and center, indicated that, (1) when the position assumed by the child at the basket, after running from the starting point, was on the side corresponding to the "preferred" hand, thus offering a convenience to the use of that hand, there was a pronounced tendency toward the use of

that hand in both the Right-handed and Left-handed groups; (2) when the position assumed by the child was center, thus offering equal opportunities for the use of either hand, there was likewise a tendency toward the use of the "preferred" hand in both groups, although in the Right-handed group this tendency was not as marked as when the position assumed was at the side corresponding to the "preferred" hand; (3) when the position assumed by the child at the basket was at the side opposite to that of the "preferred" hand, there was considerable variation, some children favoring the "preferred" hand primarily, some showing marked favor for the non-preferred hand, and some showing no marked preference for either hand.

When a single object was to be secured, under conditions calling for rapid, spontaneous choice of hand, and where approach to the basket in a straight line from the starting point was rendered the feasible method of approach, the majority of children in both the Right-handed and the Left-handed groups favored their "preferred" hand more frequently than the non-preferred, many of them using the preferred hand consistently in all three trials. However, the results in this three-trial series did not differ from the results in a given daily series of three trials in section 2 of this test, where approach to the basket to the right or left of a straight line from the starting point was not precluded, to any greater extent than did the results of any of the daily series in section 2 differ from the others.

3. No constant relationship appeared to exist between position assumed by the subject and manual "types", that is, right-handed or left-handed children; as relatively few children in either the Right-handed or Left-handed groups consistently maintained the same position in all trials of sections 1 and 2 of the Picking-up-toy test, or even in any single section. However, there was a marked tendency on the part of the majority of children in the Right-handed group, when running from the starting point to the basket in that section of the Picking-up-toy test in which one object was to be secured, to assume a position on the side corresponding to the "preferred" hand more frequently than at the left or center. In the Left-handed group, the majority of

the subjects favored center position primarily, although there was some individual variation. In that section of the test in which two objects, adjacent to each other, were employed as stimuli to reaction, center position was assumed more frequently than either right or left, by both the Right-handed and the Left-handed groups. In the Right-handed group, the right position was favored next in degree of frequency in this section; in the Left-handed group, the left position was next in favor.

4. Direction of orientation after the desired object or objects had been secured, in the Picking-up-toy test, was inversely related to the position assumed by the subject as he grasped the object. Thus, when the child stood at the right of the basket, direction of turn after the object had been seized was almost invariably toward the left; and when the position assumed was at the left of the basket, direction of turn was almost invariably toward the right. This was true of all three handedness groups.

When center position was assumed, there was some individual variation, although all three handedness groups showed a marked preference for the left turn.

5. No specific relation was found to exist between direction of orientation after the object had been secured and manual choice. This was studied in that section of the Picking-up-toy test in which the adoption of a center position was facilitated by the nature of the experimental conditions. In both the Right-handed and Left-handed groups, the children tended to fall into 3 groups with reference to direction of turn following manual choice, as follows: (1) those who consistently evidenced an inverse relationship between manual choice and direction of orientation, turning left after using the right hand, or turning right after using the left hand; (2) those who consistently evidenced a direct relationship between manual choice and direction of orientation; (3) those who varied between these two methods, showing a direct relationship in some trials and an inverse relationship in others. This last group was the largest of the three in both the Right-handed and Left-handed divisions. As all three of these tendencies were noted in both the Right-handed and Left-handed groups, no consistent relation could be assumed between direction of

orientation after the desired object had been secured and manual "types"—that is, the habitually right-handed or left-handed.

6. While none of the children in either the Right-handed or the Left-handed group used the "preferred" hand exclusively in all trials of all three handedness tests, the majority of the children in both groups showed a strong bias for their "preferred" hand in all tests given under all conditions, except in that section of the Formboard test in which an inconvenience was imposed on the use of the "preferred" hand. There was some individual variation, however, in that a few children in each group used their "preferred" hand primarly under all conditions, even when an inconvenience was imposed upon its use; and a few children used their "non-preferred" hand primarily, not only when an inconvenience was imposed upon the use of the "preferred" hand in the Formboard test, but also in section 2 of test 3 where this condition was not involved.

7. The results of these various tests of handedness seem to indicate the existence of "degrees" of manual bias, ranging from a pronounced preference for either the right hand or the left hand, to a relatively ambidextrous state where neither hand is definitely favored, or where the hand "convenient" under the circumstance is favored. The two manual types designated conventionally as "right-handed" and "left-handed" apparently indicate "trends" rather than two distinct classes, at least in so far as activities of the type used in these tests are concerned. Since factors of convenience apparently predispose to the use of the "convenient" hand—practically exclusively when the convenient hand is also the habitually preferred hand, and to varying extent when the convenient hand is the non-preferred hand—it might be that the nature of manual choice under conditions offering equal opportunity for the use of either hand, is diagnostically more significant in ascertaining these "trends" than is the nature of choice when objects are conveniently located with reference to the one hand but inconveniently located with reference to the other. If we assume that a test becomes an adequate measure of these native "trends" in so far as the results of the test agree with the "facts of the case", as determined by report of the parents,

then on the basis of the data given in this report we may assume that a test of the type of the marble board, given under conditions offering equal opportunity for the use of either hand as in this study, affords a means of ascertaining these "trends". Results obtained in this report indicate that the Picking-up-toy test, under the conditions given, is apparently less satisfactory for that purpose. A test of the type of the Formboard, given under conditions obtaining in this study wherein a convenience was offered to the use of the "preferred" hand in the manipulation of the forms lying on one side, but an inconvenience was offered to that hand in the manipulation of the forms lying on the other side of the board, seems to provide a method of ascertaining the "degree" of manual bias.

II. LEARNING SERIES

This study was conducted for the purpose of ascertaining whether the performance of the non-preferred hand improved with practice, and whether the performance of the preferred hand would show signs of improvement after the practice series by the non-preferred hand, suggesting transfer of training. Two learning series were given, one dealing primarily with the speed of learning, and the other with the accuracy of learning.

Series 1: Speed of learning

Twenty-seven pre-school children, ranging in age from 2 years 2 months, to 5 years 6 months, were the subjects. In the analysis of the data, however, the children were divided into two sections, due to the fact that the performance of some of the children did not lend itself to a study of learning effects for reasons which will be discussed later. There were 21 children, ranging in age from 2′ 11″ to 5′ 6″, in the section in which learning effects were studied. These children were divided into two groups, Right-handed and Left-handed, on the basis of their daily manual bias as reported by the parents, and by observers at the Child's Institute. In the Right-handed group there were 17 children, of whom 3 were five-year-olds, 6 were four-year-olds, 7 were three-year-olds, and one was a two-year-old within one month of her

third birthday. In the Left-handed group there were 4 children, of whom one was a five-year-old, one a four-year-old, and 2 were three-year-olds.

Apparatus and procedure. A wooden peg-board, approximately 12 inches square, and $\frac{7}{8}$ of an inch thick, containing 36 holes one-half inch in diameter, placed in six rows or columns of six each, equidistant from each other, was used. This board was painted in three colors of approximately equal intensity and brightness. One section, comprising one-third of the board and containing one-third of the holes, was blue; the second or middle section was orange; and the third section was green. A wooden knob was screwed into the side of the board, about midway, at the blue section. Thus, when the board was so placed that the knob was at the child's left, the colored sections from left to right were: blue, orange, green; and when the knob was at the child's right, the colored sections from left to right were: green, orange, blue. There were 36 pegs, each 3 inches in length and a little less than a quarter of an inch in diameter, which fit snugly into the holes. These were painted in colors corresponding to the sections of the board: 12 blue, 12 green, and 12 orange.

Each child was given a series of five trials with the non-preferred hand—that is, the hand not used habitually in unimanual activities nor in the major part of bimanual activities—and two trials with the habitually preferred hand. These trials were given daily over a five-day period in the following order:

17 RIGHT-HANDED CHILDREN			4 LEFT-HANDED CHILDREN		
Days	Trials		Days	Trials	
1	(1) R.H.	L.H.	1	(1) L.H.	(2) R.H.
2		L.H.	2		R.H.
3		L.H.	3		R.H.
4		L.H.	4		R.H.
5	(1) L.H.	(2) R.H.	5	(1) R.H.	(2) L.H.

Thus, each child in each group had five daily practice periods of one trial each with its non-preferred hand, this practice period being superseded and followed by one trial with the preferred hand.

The peg board was placed on a table approximately 21 inches high. The handle on the side of the peg board was toward the left when the right hand of the child was to manipulate the pegs, and toward the right when the left hand was to do the manipulating. A box the length of the peg board and about eight inches wide and two inches high, containing the colored pegs, was placed at the side of the peg board, opposite the side in which the handle was located, so that the pegs were within easy reach of the "active" hand, that is, the hand doing the manipulating. The pegs were well mixed in the box. The child was seated on a small chair before the table. Instructions were given as follows:

"Do you see this board and these pegs? I want you to put a peg into each of these holes as quickly as you can. Put one peg in at a time. Do you see these *blue* pegs (picking up one of the blue ones)? This peg looks just like this part of the board, doesn't it (holding the blue peg against the blue section)? Now, I want you to put all of the pegs that look just like this (indicating the blue peg) in this part of the board (indicating the blue section, and illustrate). And this *orange* peg looks like this part of the board, doesn't it (holding an orange peg against the orange section)? I want you to put all of the pegs that look just like this orange one in this part of the board (illustrating). And, this *green* peg looks just like this part of the board, doesn't it (holding a green peg against the green section)? I want you to put all of the pegs that look just like this green one in this part of the board (illustrating). (Then, removing the pegs from the board and putting them back into the box, continue):

"Now, I want you to hold on to the knob with *this* hand (indicating the "non-preferred" hand) and to put the pegs in the peg-board one at a time with *this* hand (indicating the "preferred" hand). When I say "Ready, go!", put them in as fast as you can. Ready! Go!"

The stop watch was started as soon as the child took up the first peg, and was stopped as soon as the last one was placed. On the first and fifth days, when each hand was given a trial, the pegs were removed from the board and placed back into the box by the experimenter, although at times the little subject insisted upon helping. The board was then reversed so that in the second trial on the first day the handle was on the side of the "preferred"

hand, and the box of pegs was on the side of the "non-preferred" hand. The experimenter placed the "preferred" hand of the child on the handle, instructing him that in this trial he was to hold the handle with that hand, and to place all of the pegs with the other hand, indicating the "non-preferred" hand. Instructions and illustrations were given again with reference to matching the pegs to the portion of the board correspondingly colored.

Record was taken by the observer of the following: (1) time, (2) errors in color matching (3) tendency to remove the "inactive" hand from the knob, or to maintain a constant hold, (4) tendency to aid with the "inactive" hand, (5) factors which might have influenced the child's performance on a given day. The data of chief interest in this study were those relating to the time taken in placing the pegs.

Results.—

Right-handed group

The daily average time scores made by this group, together with the average deviations, are as follows:

	FIRST DAY		SECOND DAY	THIRD DAY	FOURTH DAY	FIFTH DAY	
	Hand						
	R	L	L	L	L	L	R
Time	2′ 58″	3′ 18″	2′ 48″	2′ 34″	2′ 21″	2′ 21″	2′ 9″
A.D.	52″	46″	47″	35″	33″	31″	25″

A definite tendency was manifested by this group toward improvement in the performance of the left hand with practice. This improvement is noted not only with reference to the score made on the first day, but also with reference to each day's performance compared with that of the preceding day, with the exception of the last day, on which the score was the same as that made on the fourth day. The average time for the practiced left hand on the fifth day was 29% shorter than on the first day. Analysis of individual records indicates that, although only two

children in this group consistently showed an improvement in each day's performance with the left hand over that of the preceding day, all of the children with but one exception made better left hand scores on the fifth day than on the first day. One child showed a decline in performance of the left hand on the fifth day as compared with the first, although his performances on the second, third and fourth days respectively were better than on the first day.

An improvement was likewise noted in the unpracticed right hand on the fifth day compared with the first, the average time for the preferred hand after the practice series by the non-preferred hand being 27% shorter than on the first day, before the practice series by the left hand. Individual records indicate that with but one exception the children in this group all showed an improvement in the unpracticed right hand on the fifth day, after the practice series by the left hand. The subject who showed no improvement was somewhat petulant on this fifth day, and although she performed the first trial with good grace, she became sulky when told to put the pegs in another time, but with the right hand, saying as she worked "I've put them in once, that ought to be enough."

The average time scores for the group indicate that the right hand performance on the first day was superior to that of the left hand. This was also true on the last day, after the practice series by the left hand. Individual records indicate that 14 children in this group made a better score with the right hand than with the left on the first day, and three made a better score with the left hand than with the right, on that day. On the fifth day, 12 subjects made a better score with the unpracticed right hand than with the practiced left hand; 3 made a better score with the left hand than with the right; and 2 made the same score with each hand.

Many factors were noted which apparently affected the performance of a child and the resulting time score. Not infrequently, a child would stop in the midst of his performance, holding a peg above the board as he asked a question of the observer; and, in many cases, as the child worked, he would chat

about some matter of great interest to him—his little sister, his sore finger, the blue smock the observer was wearing, which was just the color of the blue pegs! Again, a child would stop for a few seconds on completing one colored section, and exclaim, "*Now* all the blue ones are finished!" clapping her hands in joy. Occasionally a child would remark, "I don't think I'll go fast to day; I want to go slow!" and would suit the action to the words. Weather conditions may have influenced performance to some extent. On a very warm day, one subject declared it was too hot to play, and manipulated her pegs in an obviously languid manner.

Relatively few of the children in this group made errors in color matching, particularly after the first day. In the majority of cases, these errors were noted by the subject himself, either immediately after placing the peg, or toward the end of the trial, when the child had two or three pegs of a given color left with no holes in the corresponding colored section in which to place them. Corrections were made in almost all cases with the hand "inactive" at the time, that is, the hand with which the child had been instructed to hold the knob. Errors were not restricted to a single age group, but occurred in all except age-group five; however, they occurred with greatest frequency in the three-year group. Only one three-year-old and the two-year-old approaching her third birthday, made errors in placement after the first day.

The three five-year-olds, five of the four-year-olds, and two of the three-year-olds held the "inactive" hand on the knob throughout each of the trials, except on a few occasions when that hand was used to correct a misplaced peg, or to steady the pegs in their recesses. One four-year-old, five three-year-olds, and the one two-year-old frequently removed the "inactive" hand from the knob on the first day, and occasionally on the second day, usually to correct a misplaced peg or to steady the pegs in the holes; and one of the three-year-olds persistently refused to keep the "inactive" hand on the knob, although she used it only to correct misplaced pegs.

Left-handed group

The daily average time scores for this group, together with the average deviations, are as follows:

	FIRST DAY		SECOND DAY	THIRD DAY	FOURTH DAY	FIFTH DAY	
	Hand						
	L	R	R	R	R	R	L
Time	3′ 18″	3′ 2″	2′ 51″	2′ 31″	2′ 48″	3′ 14″	3′ 24″
A.D.	1′ 19″	1′ 5″	18′ ″	43″	1′ 11″	1′ 48″	1′ 51″

According to the average scores for this group, there was a decline in the performance of the practiced right hand on the fifth day as compared with the first, although the scores for the second, third, and fourth days, respectively, were better than for the first day. There was likewise a decline in the unpracticed left hand on the fifth day, after the practice series by the right hand, as compared with the first day.

Analysis of individual records indicates considerable variation. Two children showed an improvement in the performance of the practiced right hand on the fifth day as compared with the first, one of these consistently improving each day over the performance of the preceding day. Two subjects made lower scores in the practiced right hand on the fifth day than on the first day. With reference to the performance of the unpracticed but "preferred" left hand; one subject showed an improvement and 2 subjects showed a decline in the performance of that hand on the fifth day compared with the first; and one subject had the same time record for the left hand on the fifth day as on the first.

The average right hand score for the group on the first day was better than the average left hand score. This was also true of the performances on the fifth day. Individual scores indicate that on the first day 3 subjects made better scores with the non-preferred right hand and 1 subject made a better score with the preferred left hand. On the fifth day, 3 subjects made better scores with the right hand than with the left, and one subject made the same score with each hand.

A few words may be said about the four subjects in this group, as follows:

Subject S was 4 years, 3 months of age at the time of this experiment, which was made one year ago. At that time he was termed left-handed by his parents. Throughout this current year, however, it has been noted through daily observation on the part of the experimenter that subject S now uses his right hand practically exclusively in unimanual acts like drawing, and in the active part of bimanual activities, such as cutting with a scissors, hammering, painting. His parents likewise report that he now favors his right hand. The records for this child in this learning series indicate a decline in performance in the practiced right hand on the fifth day compared with the first, although there was improvement on the second, third, and fourth days, respectively, over the first day's performance; and on the fifth day the same score was made by the unpracticed left hand as on the first day. The right hand performance on the first day was superior to that of the left; and on the fifth day, the time consumed in the trials was the same for each hand.

Subject Bb was 3 years old at the time of this experiment He was termed left-handed by his parents. In this peg-board experiment, not only was his fifth day performance with the practiced right hand inferior to that of the first, but in only one of the five practice periods with this hand did his performance show an improvement over that of the first day. His left hand performance on the fifth day likewise showed a decline over that of the first day. On both the first day and the fifth day, the right hand performance was better than that of the left. One of the difficulties encountered in endeavoring to note practice effects in activities of children through the time score was very evident in Bb's daily performance. Whenever he made an error, which he usually observed almost immediately, he would stop and glance shyly at the examiner to see if he were observed.

Subject Ff was 5 years 2 months of age at the time of this learning series. She was a pronounced left-hander, according to the statement of her mother and observations made by the experimenter of her daily activities at the Institute. She was definitely determined to use her left hand, and greatly resented any suggestion that she should use the right hand, saying defiantly, "My father said that I should use my left hand and *not* my right." Throughout the experiment she appeared exceedingly disinterested, and apparently used her right hand as directed because her mother had requested her to do as the experimenter desired.

Subject Ee was 3 years 11 months of age at the time of this experiment. According to the statement of his mother, and observations of his daily activities made by the observer at the Institute, he was decidedly left-handed. He was very much interested in the peg board and was very eager to work as speedily as possible, not resenting the necessity of using the right hand. His performance shows an improvement in the practiced right hand, not only on the fifth day as compared with the first, but on each successive day as compared with the preceding day. The left hand likewise showed considerable improvement on the fifth day as compared to the first, the time of manipulation being approximately 35 per cent less on the fifth day than on the first.

The three older children in this group made no errors in placement, but the three-year-old, Bb, made frequent errors. Sometimes they were noted by him immediately and corrected with the hand that was holding the knob; again they were not observed until the end of the trial, when there was a colored peg left with no place in the correspondingly colored section in which to put it. Frequently this subject would place the pegs incorrectly in an apparent spirit of mischief, glancing laughingly at the observer, and saying "See!" He would then remove it and place it correctly.

Two subjects, S and Bb, kept the inactive hand on the knob throughout the trials, although on the first day each of these subjects occasionally aided their performance with the inactive hand. Bb used the right hand to hold some of the pegs, as the left hand placed them, on the first day; and S, upon noting a misplaced peg, hastily adjusted it with the inactive hand. Ff did not maintain a firm grasp on the knob at any time, and frequently used the inactive hand to correct errors throughout the series of trials. Ee frequently removed his left hand from the knob on the first and second days when the right hand was doing the "active" part of the performance, and would reach over with his left hand and pick and place a peg occasionally. By the third day, however, he was holding firmly to the knob.

Six of the 27 subjects employed in this study ranged in age from 2 years 2 months, to 2 years 10 months. A learning series

was not conducted with this group, for the following reasons: (1) Although all of these subjects seemed to grasp the idea that the pegs were to be placed in a certain way, the nature of the placing—that is, the matching of the pegs to the part of the board corresponding in color—was comprehended by only two of these subjects. The remainder would place a green peg in the blue or yellow section, and glancing inquiringly at the observer, ask, "Dis go here?" (2) Of the two who apparently comprehended the nature of the task, one, a child of 2 years 7 months, was tested too late in the year to warrant a practice series. This subject, in the two trials made by him, made only a few errors in placing, and these he observed and corrected. He was attentive throughout the trials, was very much interested, and exceedingly swift, comparing favorably with the three and four-year-olds. The other subject, a child 2 years 10 months of age, although apparently comprehending the task, would soon weary of the color matching, and hilariously return to indiscriminate placing. It may be that the number of pegs to be placed rendered the task too long for the child's span of attention. After the daily instructions, he would place a dozen or so of the pegs correctly, glancing at the observer and saying "dis go here?", then he would become very playful and dance about in front of the table, placing the pegs on top of one another. (3) The concept of speed apparently has little meaning to many children at this age. The child below three years of age plays a great deal, claps his hands after putting in a peg, experiments by putting pegs on top of other ones before finally placing them, makes "funny" faces while working, or glances shyly at the experimenter as he fumbles with the pegs.

Series 2: Accuracy in learning

Five children, ranging in age from 4 years 4 months, to 5 years 5 months, were the subjects. Four of the children were right-handed and one was left-handed.

Apparatus and procedure. The activity chosen was that of throwing a solid rubber ball, 2 inches in diameter, through a steel hoop, 7 inches in diameter, into a bag of muslin fitted securely around the hoop. The hoop was firmly secured at the top and

bottom by means of snappers fastened to the upper and lower arms of an upright iron rod, which was approximately 5 feet in height. The muslin bag was held at the center by another snapper, suspended by means of a rubber band from the iron rod about midway between the two arms. This prevented the bag from dropping below the steel hoop, and formed a cornucopia into which the ball fell when it went through the hoop. As the arms, or horizontal bars, were movable, it was possible to adjust the hoop to the height of the child, so that when the arm of the subject was extended straight forward from the shoulder, it was in line with the center of the muslin bag. Each time the ball went through the hoop into the bag it was counted a success, regardless of whether it stayed in the bag or rolled out, as the object was to throw the ball *through* the hoop, and the bag was attached merely as a means of preventing the ball from striking against the wall.

A line was drawn with yellow chalk on the floor, three feet three inches from the hoop. The child was instructed to stand on this line when he threw the ball. It was estimated that when the child's hand was raised in position to throw the ball, the hand would be about 3 feet from the hoop.

Each child was given 125 trials with the non-preferred hand and 50 trials with the preferred hand. These trials were given daily over a five-day period, in the following order:

4 RIGHT-HANDED CHILDREN			LEFT-HANDED CHILD		
Days	Trials		Days	Trials	
1	(1) 25 R.H.	(2) 25 L.H.	1	(1) 25 L.H.	(2) 25 R.H.
2		25 L.H.	2		25 R.H.
3		25 L.H.	3		25 R.H.
4		25 L.H.	4		25 R.H.
5	(1) 25 L.H.	(2) 25 R.H.	5	(1) 25 R.H.	(2) 25 L.H.

Thus, each child had five practice periods of 25 throws each with its non-preferred hand, this practice period being superseded and followed by one trial of 25 throws with the preferred hand.

Instructions were given as follows:

"I want you to stand on this yellow line on the floor, and

throw the ball through the hoop into the bag with this hand (indicating the hand by placing the ball in the subject's "preferred" hand). You are going to have twenty-five trials, and we want to see how many times you can get the ball to go right through the hoop into the bag."

On the first day, after the first trial of twenty-five throws with the preferred hand, the ball was placed in the child's non-preferred hand, with the instruction that he was now to have twenty-five throws with that hand. Each day the ball was placed by the observer in the hand which was to do the throwing, with the instruction, "we are going to use *this* hand today."

Results. The daily scores, indicating the number of correct throws made in each series of 25 trials by each child in the Right handed group, is given below:

SUBJECT	FIRST DAY		SECOND DAY	THIRD DAY	FOURTH DAY	FIFTH DAY	
	Hand						
	R	L	L	L	L	L	R
N	7	6	2	4	4	2	3
R	9	12	8	5	6	9	13
S	8	8	11	12	11	15	11
U	10	10	6	4	9	14	18

Little evidence of improvement with practice in the performance of the non-preferred hand, over the five-day period, was given by any of the children in this group. Two subjects, N and R, made their highest score in the practiced left hand on the first day, showing no tendency to improve with practice. Subject N also showed a decline in the performance of his unpracticed right hand on the fifth day as compared with the first, while subject R showed some improvement in his hand. Two subjects, S and U, made better scores with the left hand on the fifth day than on the first; however, on the second, third, and fourth days, respectively, U made lower scores than on the first day, while S showed some improvement. Both S and U made better scores in their unpracticed right hand on the fifth day than on the first day.

The daily scores of the left-handed subject, Ee, are as follows:

FIRST DAY		SECOND DAY	THIRD DAY	FOURTH DAY	FIFTH DAY	
Hand						
L	R	R	R	R	R	L
7	9	10	9	8	12	15

While this subject showed an improvement in the practiced right hand on the fifth day compared with the first, little improvement was shown on the intervening days. The greatest extent of improvement occured in the unpracticed but "preferred" left hand on the fifth day compared with the first.

None of the four right-handed children showed a tendency to use the right hand to throw the ball during the left-hand series. The left handed child, however, would frequently transfer the ball from the right hand to the left hand, just as he was about to throw. He made no objection when the observer instructed him to use the other hand, and laughingly complied. Apparently he was not wilfully disregarding instructions, but the tendency to use the left hand in throwing may have been so strongly established that it was difficult to inhibit.

Summary. A practice series given to a group of pre-school children in the use of the "non-preferred" hand, preceded and followed by one trial with the "preferred" hand, in the placing of colored pegs within the sections of a peg board of corresponding colors, indicated the following significant responses:

1. In the Right-handed group, a marked tendency was shown toward improvement with practice in the performance of the "non-preferred" left hand. Improvement was also noted in the performance of the unpracticed right hand on the last day of the test, following the practice series by the left hand, as compared with the performance of the right hand on the first day, suggestive of transfer of training. The majority of the subjects in this group made better scores with the right hand than with the left hand on the first day of the test, as well as on the last day, after the practice series by the left hand.

2. In the Left-handed group, average daily scores indicated an improvement in the practiced right hand on the second, third, and fourth days, respectively, as compared with the first day; however the performance on the fifth day fell below that of the first. Individual records showed considerable deviation from group averages. One child showed a marked improvement daily in the practiced right hand over the score of the preceding day; two children showed some slight improvement in practice, although they varied from day to day; and one child showed no tendency toward improvement in the right hand performance with practice. The average scores for the unpracticed left hand on the fifth day as compared with the first showed no improvement in that hand; however, individual performances showed variation in this respect.

3. Various conditions were noted which might have influenced the daily variations in performance: (1) the mood of the child, brought about presumably by weather conditions, or physical conditions; (2) deviation of the child's attention from the situation in hand to some matter of interest to him, brought about by environmental features, or the general trend of his thoughts; (3) disregard of the time element through keen enjoyment in his production, expressed in actions and words which consumed time.

4. This test proved inadequate, on the whole, as a learning series for children under three years of age, for the following reasons: (1) lack of comprehension of the nature of the task, namely, the matching of the colored pegs to the correspondingly colored sections of the board; (2) the span of attention of children below the age of three apparently did not warrant the completion of a test of the length given, under the imposed condition of color matching; (3) the concept of speed apparently has no meaning to children below the age of three years. These are suggested reasons, only, as the number of children tested under the age of three years was not sufficiently large to warrant the drawing of conclusions.

A practice series given to four right-handed children and one left-handed child of pre-school age in throwing a solid rubber

ball through a steel hoop at a distance of three feet, indicated variation in performance. Three of the right-handed children showed little indication of improvement in the practiced left hand; and one of the right-handed children and the left-handed child showed some improvement in their practiced "non-preferred" hand, although this improvement was not pronounced in either case. With the exception of one right-handed child, all of the subjects improved in their unpracticed "preferred" hand on the last day compared with the first day.

III. TRAINING LEFT-HANDED CHILDREN IN THE USE OF THE RIGHT HAND

This study is concerned with the development of a method of training two left-handed children in the use of the right hand. Two practice series in motor activities of different types were given, one type involving the finer muscle coördinations, and one involving the gross muscle coördinations. The following conditions were observed by the experimenter in each test series:

(1) Bimanual activities were used of the type in which there was a major, active function, and a minor, accessory function. By this means the left hand was kept occupied in order to offer a relief for any tension which might be present due to the inhibition of the impulse to use the habitually preferred hand.

(2) Activities were chosen which were relatively new to the child in order to prevent, in so far as was possible, conflict with reactions which had become fixed.

(3) The endeavor was made to permit no suggestion to creep in that it was possible to use the left hand for the major part of the activity. When, despite this endeavor, a subject took the object of manipulation in his left hand, the experimenter transferred it back to the right hand as quickly as possible, in order to prevent the tendency to use the left hand from developing into explicit action. This transfer was also made as quietly as possible, in order to guard against emotional disturbance on the part of the child.

(4) Attempts were made to retain the interest of the child through various features of the test, and through competition with another child.

Two subjects were used. One subject, Ff, was a girl, five years old; the other, Ee was a boy, 4 years 3 months of age. Both children were decidedly left-handed, according to the statement of the parents, and the observations made by the experimenter of their preferential manipulation in daily activities engaged in at the Institute.

First test series

Procedure and apparatus. The Johnson Coördination test was used in this practice series, which involved the minute muscle coördinations. The form used is illustrated in Johnson (11). Two trials were given daily over a period of ten days or more. The right hand traced the path through the maze, while the left hand held a hard rubber ball, resting upon the table.[2] The paper was fastened by means of thumb tacks to a large board which was placed upon the table. A metronome, placed on the table before the child, was timed at 60 beats per minute.

Instructions were given as follows: "You are to draw a line in the path between these black lines, making a stroke with your pencil each time this clock ticks (illustrate by making a stroke of the pencil in a given segment to the beat of the metronome). Be careful not to touch the black lines with your pencil." The pencil was placed by the experimenter in the right hand of the child, and the ball was placed in the left hand.

This test, and the dart throwing test next discussed, were given during the same period, the coördination test first, and then the dart throwing test. Both children were so interested in the dart throwing test that they frequently requested permission to go to the experimental room "to hit the bull's eye" immediately upon sight of the experimenter. The coördination test, however,

[2] A more adequate means of relief for possible tension in the left hand might be provided in this test, if the rôle performed by the relatively unoccupied left hand were more closely related to that performed by the active right hand. If, for example, the coördination blank were clamped to a board which was itself securely fastened in order to prevent slipping, and if the child were required to hold the clamp—a fairly good sized one so that it could be grasped in the hand—with the left hand, as he traced the pathway with the pencil held in the right hand, this might be an improvement over the method used in this investigation.

was not popular with either child. As a means of securing the interest of the little subject, crayon pencils of different colors were used, and the child was permitted to choose the color he desired. Toward the end of the series of tests, the element of competitition with one of the children at the Institute in whom the subject was interested was used as a means of reviving interest in the tests.

Results. The number of contacts made by each subject in each daily test is as follows:

SUBJECT EE				SUBJECT FF			
Day	First trial	Second trial	Average	Day	First trial	Second trial	Average
1	9	—	9	1	11	—	11
2	8	11	9.5	2	9	15	12
3	9	12	10.5	3	9	6	7.5
4	14	11	12.5	4	12	—	12
5	15	14	14.5	5	8	10	9
6	15	16	15.5	6	7	12	9.5
7	8	12	10				
8	11	9	10				
9	12	6	9				
10	9	8	8.5				
11	3	4	3.5				
12	3	4	3.5				
13	3	6	4.5				
14	4	6	5				
15	3	2	2.5				

Subject Ee

The average number of contacts made by this subject daily in the two trials tends to increase from the first to the sixth day. Thereafter, he improved steadily, although on the 13th and 14th days respectively he made a few more contacts than on the 11th and 12th days, respectively.

Ee was usually very willing to come with the experimenter and to do as instructed. Toward the ninth day, however, he was apparently losing interest, so on the eleventh day the element of competition was introduced and continued throughout the remainder of this series. It will be noted that his performance on

the eleventh day, and on subsequent days, showed great improvement over his daily performances prior to the introduction of competition. On the sixteenth day he was very reluctant to perform the test, and in the midst of the first sheet, he suddenly jumped from his chair and darted from the room. No further trials were given.

This subject rarely objected to the use of the right hand, although during the first four or five days, he frequently complained that "using this hand makes me tired." On the first day one trial only was given, due to the obvious discomfort he was experiencing; and the experimenter thought it unwise to run the risk of antagonizing him against the test.

Considerable tension in the left hand, as well as in the face, was exhibited by this child on the first three or four days. The left hand quivered decidedly as he wrote, and the bright sunny smile gave way to contorted lips and lowered brows, as he laboriously traced a very irregular line through the pathways. He apparently made a strenuous effort to keep within the path and to avoid touching the heavy black lines bounding it. After the fourth day, practically no tenson was noted by the observer in Ee's left hand, nor was any evidence of discomfort manifested in his countenance.

During the early part of the practice series, when the pencil was handed to this subject, he would occasionally put down the ball which he was holding in the left hand, and hold out the left hand for the pencil. On several occasions, also, in the early trials, when the signal was given to start, he would release the ball and swiftly transfer the pencil from his right hand to his left hand. However, when the pencil was again placed by the experimenter in the right hand, and the ball in the left hand, with instructions to hold firmly to the ball, he made no remonstrance.

On the first two days, Ee started at the right of the paper and traced the path toward the left—the reverse of the usual right-hand method. For several days thereafter, the observer would point to the starting place at the left of the paper when the subject traced the first and second paths of the first sheet, but would let the child follow his own initiative in the remaining paths.

After the fourth day, he traced all paths from left to right, without suggestion from the experimenter.

Subject Ff

This subject made but little improvement with practice in the comparatively few trials given. Analysis of the performance of subject Ee during a comparable period indicates that Ee likewise showed no improvement during the first six days; in fact, he made more errors in average score on each of those days than on the first day. As Ff left the Institute after the sixth day of testing, she was not available for further experimentation.

Ff intensely disliked the coördination test and was averse to taking it. She was always eager to accompany the experimenter, as she was fond of the dart throwing test, given during the same period as the coördination test; but she submitted with ill grace to the coördination test. She was decidedly antagonistic to the use of the right hand in this test. On the first day, when the pencil was placed in her right hand, she turned belligerently to the observer, stating, "I'm not going to use my right hand; I can do it better with my left hand, and my father said I should use my left hand." Throughout the test she cast defiant glances at the observer, and finally announced, "I'm not coming to this school tomorrow; not if you make me use my right hand." One trial only was given on the first day, and a day or two elapsed before the experimenter again gave Ff the coördination test. On that day, although she made no remonstrance against using the right hand, she gave marked evidence of indifference, apparently making no effort to avoid striking the black lines bounding the path, and announcing when she had finished: "If you would let me do that with my left hand, I could do it much better." On the third day, Ff came to the experimenter and volunteered to "draw a path" for her. On the fourth day, after finishing one sheet she announced that she did not want to do any more that day. Ff seemed to waver between two influences: on the one hand, her father was apparently urging her to continue in the use of her left hand; while on the other hand, her mother was urging the child to do as the experimenter directed. The mother was desirous of

having the child use her right hand, whereas the father was apparently antagonistic thereto; in fact, on one occasion he stated to the observer that "she came by it naturally; her grandfather was left-handed."

Ff showed no discernible evidence of tension in the relatively inactive left hand, or in the face. Her performance throughout was apparently an indifferent one. Although she remonstrated against the use of the left hand, she exhibited no tendency to transfer the pencil to the left hand for use after the experimenter had placed it in the right hand. She always started at the left of the paper, and traced toward the right, in accordance with the usual right-hand method.

Second test series

Procedure and apparatus. A target board and darts were used in this practice series, which involved primarily gross motor coördination. The target board was the one used by Bates (2).

The darts were the same as those used by Johnson (10). The board was adjusted to the height of the child and this adjustment was such that when the arm of the subject was extended straight forward from the right shoulder, it was in line with the bull's eye. A cross mark in yellow chalk was made on the floor 7 feet from the target board, and the child was instructed to stand at that place while throwing the darts. Each day, for a period of 10 days in the case of subject Ff and 15 days in the case of subject Ee, the child was given thirty darts to throw with his right hand, in three trials of ten throws each. The observer competed with the child in the early part of the series, observer and subject each throwing ten darts alternately. Later, a child friendly with the subject was used as competitor. The darts were held in the left hand of the subject and were thrown, one at a time, with the right hand. In order to avoid any suggestion that the left hand could be used for the active part of this test, the darts were always placed by the observer in the child's left hand, and instructions were given as follows: "Now, we hold the darts in this hand (indicating the left hand) and throw them one at a time with this hand (indicating the right hand). Stand on this yellow cross mark (indi-

cating the mark on the floor) and try to hit the bull's eye (indicating it)." If the subject transferred the darts, prior to throwing, to the right hand to hold and endeavored to secure one with the left hand to throw, the experimenter would quickly but quietly remove the darts from the right hand and transfer them again to the left hand, saying, "we *hold* them in *this* hand and throw them with *this* hand (indicating the right hand); that is the way the game is played."

Results. The daily scores made by each subject are given below:

SUBJECT EE		SUBJECT FF	
Day	Score	Day	Score
1	6	1	22
2	8	2	33
3	12	3	37
4	10	4	30
5	18	5	33
6	34	6	23
7	36	7	33
8	40	8	29
9	43	9	34
10	66	10	67
11	84		
12	75		
13	50		
14	61		
15	56		

Subject Ee

This subject showed a marked improvement daily, from the first day through the eleventh day, with the exception of the fourth day when the score dropped somewhat below that of the third day. The score made on the twelfth day was somewhat lower than that made on the eleventh day; and the scores made on the thirteenth, fourteenth, and fifteenth days respectively were somewhat lower than those made on any one of the three days preceding the thirteenth; however, on each of the four last days the score was considerably higher than on any day prior to the

tenth. A child of whom the subject was very fond was used as a competitor on the tenth day and on all days following.

On the first five days this subject would occasionally transfer the darts which he held in his left hand to the right hand, and would select one of them with the left hand preparatory to throwing with that hand. This occurred again on the eighth day, but ceased thereafter. On the first few days, also, when the last dart of a series fell to the floor instead of hitting and sticking to the target board, this subject would pick up the dart with the left hand and swiftly throw it.

Subject Ff

While this subject showed some improvement in score with practice, in that the score of each day was higher than that of the first day, her performance did not show the steady daily improvement that was evident in the performance of subject Ee, but varied considerably from day to day. An increase was noted on the second and third days respectively over the score of the preceding day; however, the daily scores on subsequent days all fell below that of the third day, until the tenth day was reached, when there was a significant increase in score. On that day the element of competition with another child was introduced. As subject Ff left the Institute at this time, it was impossible to continue this learning series further.

A comparison between the performance of subject Ee and that of subject Ff indicates that, while Ff made a score on the first day which was approximately four times that made by subject Ee on that day, on the tenth day the scores of the two subjects were equal. The score made by subject Ee on the tenth day was eleven times that made by him on the first day, while the score made by Ff on the tenth day was but three times her first day's score.

Throughout the test series Ff was intensely interested and did not manifest any objection to the use of the right hand as she did in the coördination test. It may be that her reluctance to use the right hand in the coördination test was partly due to the fact that the left hand had been habitually used in activities somewhat

similar in type, such as drawing, scribbling, painting; whereas, in the dart throwing test she was engaged in a practically new activity in which the impulse to use the left hand was not so strongly established. It may also be that the nature of the tests —one involving the finer muscle coördinations, the other the grosser—entered into the situation.

On no occasion did Ff transfer the darts from the left hand to the right hand to hold, in order to throw with the left hand. Occasionally, however, if the last dart thrown fell to the floor, she would pick it up with the left hand and attempt to throw it.

Summary. Training of two strongly left-handed children of pre-school age, in the use of the right hand in motor activities involving gross muscle coördination as well as those involving the finer muscle coördinations, seemed possible. Individual differences were noted with respect to extent of learning, attitude toward the use of the "non-preferred" right hand, and presence or absence of observable tension in the relatively unoccupied left hand and in the face during the test involving the finer muscle coördinations. The subject who showed marked improvement in his right hand performance in both tests had made no objection to the use of that hand. In the early stages of the test series involving the finer muscle coördinations, this subject evidenced strong tension in the left hand and in the face; however, this tension apparently disappeared after a few days of testing.

Improvement was manifested earlier in the dart throwing test, which involved primarily the gross motor coördinations, than in the "coördination test", which involved the finer motor coördinations.

Both subjects occasionally transferred the dart to the left hand for use in the dart throwing test, and one subject occasionally transferred the pencil to the left hand for use during the early part of the "coördination" test; however, this tendency toward the transfer of the object of manipulation to the preferred hand was eventually subordinated.

Improvement was noted in the performance of each of these subjects when competing with another child.

IV. DAILY OBSERVATIONS

Ten daily observations of ten minutes each were made by the experimenter on 21 children, ranging in age from 2 years 4 months to 5 years, for the purpose of ascertaining the preferential use of the hands and the consistency of such preference in daily activities of the child's own choice. These children fell into three groups on the basis of their age, as follows: (a) Two-year-olds, consisting of 4 children ranging in age from 2 years 4 months to 2 years 9 months. Three of these children were reported by their parents as being right-handed, and one as being left-handed in some activities, such as writing, eating, cutting with scissors, and right-handed in others. (b) Three-year olds, consisting of 6 children ranging in age from 3 years 2 months to 3 years 9 months. These children were all reported by their parents as being right-handed. (c) Four-year-olds, consisting of 11 children, ranging in age from 4 years to 5 years. Of this group, 7 were termed right-handed by their parents, 2 were termed exclusively left-handed, and two were termed ambidextrous, in the sense of using either hand for any given activity. These three groups carried on their activities in separate rooms of the Institute, one group being on each of the three floors of the building. For purposes of analysis, these children were divided by the observer into three handedness groups, namely, Right-handed, Left-handed, and Ambidextrous. Thus, in the Right-handed group there were 16 subjects, in the Left-handed group there were 2 subjects, and in the Ambidextrous group there were 3 subjects. Where age differences were shown with respect to type of activity indulged in, or type of manipulation employed, such differences were noted.

Method. The observer entered the room of a given age-group each morning at approximately the same time. Seating herself in the vicinity of the first child to be observed, she would spend some time in writing, without paying attention to any of the children, before beginning her observation. The reaction on the part of the children toward her presence was different in the three groups. In age-group two, shyness was occasionally manifested

when the experimenter entered the room. The children would stop in their activities and glance shyly at her; or, as in the case of subject Cc, would immediately attempt to claim her attention. This same attitude was directed toward other adults when they entered the room. After a few minutes the children would seem again at ease; and after a few daily visits to the group, there was nothing more than a shy glance or a smile directed toward the observer when she entered. The children in age-group three paid little or no attention to the observer. They were usually hilariously intent upon their own activities, and upon each other. In age-group four the observer was usually greeted by several of the children. She would respond with a "good-morning" and then return to her notebook activities. The children in this group gave no apparent evidence of embarrassment at the presence of the observer, nor did they seem aware that they were being observed.

Each day the experimenter took notes in shorthand of the activities of five or six children, observing each of them singly for a ten-minute period. Note was taken of: (1) the activities indulged in, (2) the hand used in unimanual operations, (3) the hand doing the major or "active" part of bimanual tasks, (4) conditions which might be contributory to the use of a given hand. This material was then organized so that a list was made for each child of the different activities indulged in, the number of times each activity was noted during the ten periods, and whether the use of the hands in a given activity was consistent throughout.

An attempt was made to classify the various activities observed into unimanual and bimanual types. One runs into difficulties here, for in many cases an activity which is in itself unimanual is attended by contributory activities making up a total situation. For example, while painting and drawing are unimanual activities in that one hand only manipulates the brush or pencil, yet the child usually engages his relatively unoccupied hand in an activity contributory to the main activity. He may hold the paint brush or crayon in the right hand as he wields it back and forth, and hold the left hand on the paper, perhaps steadying it. He may hold the paper in the left hand, as he manipulates the scissors with the right hand; or hold the nail with one hand as the other

hand strikes with the hammer. In other cases, an activity may be unimanual at times and bimanual at other times. The peg board, for example, may be an entirely unimanual activity, in that the child picks up and places the pegs with one hand throughout; or it may be bimanual in that one hand picks up the pegs and the other hand places them; or one hand may pick them up, pass them to the other hand to hold, and the first hand then takes them one by one from the second hand and places them. Carrying a cup of milk, or lifting it to the mouth, may likewise be unimanual or bimanual; although in this case, the nature of the bimanual activity is apparently somewhat different from that of the peg-board activity, in that the two hands coöperate in performing the same *type* of function—namely, steading the cup; whereas in the peg-board activity mentioned above the function of the two hands differs. The manipulation of plasticine, although bimanual in nature, may be different in form: for example, it may be moulded by the two hands coöperating in the some function, each of them kneading, moulding, forming, although perhaps in varying degrees; or it may be performed as an activity in which one hand has an active rôle, and the other hand a relatively passive rôle, as when the child holds the plasticine on the work table with one hand, and cuts off pieces of it with a tiny stick held in the other hand, or punches holes into it with a file held in the other hand. From one point of view the performance of each hand may be treated as a separate act; whereas from another point of view, the function of each hand may be treated as a part of a total activity making up a total situation. This latter is the point of view adopted in this paper. In the case of painting, drawing, cutting with scissors, where both hands are involved, one in the performance of a major task, the other in an accessory task, the two hands function simultaneously in the total situation or activity. In the case of the peg board, under conditions when one hand is engaged in picking the pegs, and the other in placing them, the hands function not simultaneously, but successively, and both activities are included in the total situation.

The forms of manipulation, then, have been classified as follows:

1. Unimanual acts: those which involve the use of one hand only. The "inactive" hand may be aiding in the performance of the task in so far as, in any integrated activity, the whole organism functions; however, it is not observable that the extent of aid given by the "inactive" hand is greater than that rendered by any other part of the organism.

2. Bimanual-1 acts: those in which both hands coöperate either sequentially or simultaneously to effect the completion of a total situation. In this particular type of activity, one hand assumes a major function, while the other hand assumes an accessory function, with each function differing from the other in kind and degree.

3. Bimanual-2 acts: those involving the coöperation of both hands and in which the function of the two hands is the same in kind, though perhaps not in degree.

The activities observed are listed below, under the three forms of manipulation noted above. Where an activity was performed in more than one way, it is listed under each of the respective headings.

I. Unimanual acts

(1) Picking up objects
(2) Carrying objects
(3) Serving milk and crackers
(4) Handing objects to others
(5) Accepting objects from others
(6) Wiping the table, floor, or blackboard
(7) Pulling a wagon
(8) Lifting a cup of milk to the mouth
(9) Lifting a cracker to the mouth
(10) Drawing with chalk on the blackboard
(11) Peg board
(12) Block building
(13) Ball throwing

II. Bimanual-1 acts

(14) Drawing with crayon on paper
(15) Writing
(16) Painting
(17) Brushing over cubes of paint
(18) Swirling a brush about in a jar of water
(19) Stamping numbers on paper with a rubber stamp

(20) Cutting out pictures, numbers, or designs, with scissors
(21) Brushing over cut-outs with a paste brush, and fastening them to a cardboard or other background
(22) Plasticine, used as an object worked upon by another tool
(23) Sandpapering blocks, or other wooden objects
(24) Manipulating implements, such as a saw, hammer, chisel, vise, screw driver
(25) Placing pins with colored celluloid tops in a beaver board
(26) Pinning a picture to burlap stretched against the wall
(27) Peg board
(28) Playing with blocks
(29) Stringing beads

III. Bimanual-2 acts

(30) Carrying objects
(31) Lifting a cup of milk, or cracker, to the mouth
(32) Serving milk, or crackers
(33) Moulding plasticine
(34) Sweeping.

Table 4 shows the frequency with which each child performed the various activities during the ten observation periods.

Results.—

Right-handed group

I. Unimanual acts. When unimanual acts such as picking up and carrying desired objects, picking up objects which have fallen, handing articles to or accepting them from others, picking up a cloth and wiping the table, floor or blackboard: when such acts were performed under conditions in which both hands were unoccupied and the object was equally accessible to either hand, the right hand was favored practically always by the children in all three age-groups. When, however, factors of convenience were involved, manual choice was apparently affected accordingly. Thus, when the child went to the shelf or table for a paint brush and paper, he would usually reach for one of these with the right hand. On some occasions, the child would carry this to his work table, and return for the second article, which he would usually secure with the right hand. As a rule, however, the child would, after securing the paint brush or the paper with the right hand, reach for the second object with the unoccupied left hand, particularly if the second object were in proximity to the

TABLE 4

Frequency of performance by each child of the various activities

ACTIVITY	RIGHT-HANDED GROUP																LEFT-HANDED GROUP		AMBIDEXTROUS GROUP			TOTAL FOR GROUP
	Two-year group			Three-year group						Four–five-year group							Four–five-year group		Two-year group	Four-year group		
	B	C	D	F	G	H	I	J	K	N	O	P	R	S	T	U	Ee	Ff	Cc	Jj	Kk	
(1)	8	9	6	2	4	8	8	4	3	7	4	—	4	2	3	5	10	11	10	8	10	126
(2)	6	9	5	2	8	7	8	1	3	4	3	—	4	—	3	4	6	9	6	4	7	99
(3)	—	—	—	—	—	1	—	—	—	1	1	—	—	—	1	—	1	—	—	—	—	5
(4)	—	1	1	—	—	—	—	—	—	3	—	—	—	—	—	—	4	—	2	—	—	11
(5)	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	4
(6)	—	—	2	—	—	1	1	1	—	2	2	1	—	—	—	—	1	—	1	—	2	14
(7)	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	1	2	—	1	6
(8)	—	—	—	—	—	1	—	1	—	—	—	—	2	3	1	1	2	—	1	—	—	12
(9)	—	1	1	—	1	2	1	1	—	3	2	—	2	3	1	1	2	—	—	—	—	21
(10)	—	—	—	—	—	1	—	—	—	1	3	4	2	2	—	1	2	—	—	—	—	16
(11)	1	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	7
(12)	1	—	—	—	1	3	—	2	2	1	—	—	—	—	1	—	1	—	—	1	1	14
(13)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
(14)	—	3	3	—	3	1	1	3	1	—	5	—	3	2	—	3	3	2	1	2	1	37
(15)	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3	—	5
(16)	4	5	4	—	5	4	5	1	—	1	4	—	3	2	7	4	4	7	4	—	3	67
(17)	4	5	—	—	5	4	5	1	—	1	4	—	3	2	7	4	4	7	4	—	3	63
(18)	4	5	—	—	5	4	5	1	—	1	4	—	3	2	7	4	4	7	4	—	3	63
(19)	—	—	—	—	2	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
(20)	1	1	1	2	1	2	3	7	1	4	3	1	5	2	3	1	3	3	3	2	3	52
(21)	—	—	—	1	—	—	1	3	3	4	—	—	3	1	2	2	2	2	—	1	2	27
(22)	4	2	5	—	—	—	—	—	—	1	—	2	1	—	—	1	3	—	3	—	—	22
(23)	—	—	—	—	—	—	—	—	—	2	—	—	—	2	—	—	1	—	—	—	—	5
(24)	5	2	2	6	1	6	4	6	7	2	—	—	2	3	5	3	3	7	4	5	3	76
(25)	—	—	—	1	2	—	2	—	—	—	—	5	—	—	—	—	—	1	—	—	—	11
(26)	—	—	—	—	3	—	3	1	1	—	—	—	2	—	3	1	3	3	—	—	—	20
(27)	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
(28)	1	—	—	—	—	—	—	—	—	1	2	—	—	—	—	1	—	2	—	—	—	7
(29)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
(30)	—	4	2	—	1	—	—	—	—	3	2	—	2	—	—	—	—	—	1	—	1	16
(31)	2	2	—	—	—	1	1	—	2	3	2	—	—	—	—	—	—	—	1	—	—	14
(32)	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	1	—	—	—	—	—	4
(33)	4	—	—	—	—	1	1	—	—	1	—	1	—	—	1	1	—	2	—	—	2	14
(34)	—	—	—	—	—	1	1	—	1	1	—	—	1	—	—	—	1	—	—	—	—	6

first one, and would carry them back to his work table, one in each hand. Subjects C and D, in the two-year group, were observed on one occasion each to reach for a play object with the left hand, although the right hand was unoccupied. On each of these occasions the desired object was on a shelf placed at such a height that it was necessary for the child to stand on tiptoe. In one case, the object was at the extreme left, thus more readily accessible to the left hand. In the other case, the object was at the right; however, a projecting board at the right rendered the article more easily accessible to the left hand in reaching than to the right; and the right hand was used by the child as a means of steadying the body.

When the right hand was occupied, and something dropped to the floor, the left hand was used to pick up the object; unless the object was more readily accessible to the right hand, in which case the right hand usually relinquished what it held and secured the dropped object. When tools of manipulation such as the scissors, the paint brush, or crayon, were readily accessible to the left hand rather than the right they were picked up by the "convenient" left hand; however, they were invariably passed immediately to the "preferred" right hand for manipulation. When the right hand held something with which the child had been actively working, the left hand picked up other accessories. For example, one morning subject B was observed standing in a pen filled with blocks of wood, holding in his right hand a heavy hammer, while with his left hand he was picking up and throwing out blocks of wood. Still grasping the hammer in the right hand, he climbed over the side of the pen, supporting himself with the left hand, and hammered vigorously with the right hand on the boards he had thrown out. It was noted, however, that even though the right hand were occupied with one object, and another object was desired which was to be actively manipulated, the first object was usually released by the right hand which then picked up the second object. Thus, when going to the box of nails with the hammer held in the right hand, subject F picked up the nails with his unoccupied left hand. However, when getting the saw, although he was still holding in his right hand the hammer he had

been using, and although the left hand was unoccupied, subject F first put down the hammer and then picked up the saw with the right hand, actively manipulating it with that hand.

Serving milk to the children in the group was performed by one subject in the three-year group, subject H; and by two children in the four-year group, subjects N and O. Subject H carried the cups, one by one, by the rim with his right hand, and handed them to the children or placed the cups in front of the children, with the right hand. The method adopted by subjects N and O respectively was sometimes unimanual and sometimes bimanual. The hand used in the unimanual performance apparently depended upon the position of the handle; that is, when the cup was so placed on the tray that the handle was toward the right, the child grasped the handle by the right hand, and when it was turned toward the left, the child used the left hand. Usually, however, the unoccupied hand supported the side of the cup opposite the handle.

In the two-year age group, lifting a cup of milk to the mouth was a bimanual performance, according to the few occasions noted. Holding a cracker while eating it was a bimanual performance on two occasions, and unimanual on three occasions. The right hand was used when the performance was unimanual.

In the three-year age group and in the four-year age group, the method of manipulation employed with the cracker and cup of milk when eating, varied with different children, and sometimes on different days or during the same day with a given child. The following methods were noted:

(1) Holding the cracker in the right hand while eating the cracker; then placing it on the table in order to pick up the cup of milk with one hand. The right hand was always used when the manipulation of the cup was unimanual, and was usually held by the handle, though occasionally a subject held it by the side. The latter method was used when the handle was toward the left; however, it was usually followed by a bimanual method, in that the left hand would be used to support the handle.

(2) Holding the cracker in the right hand while eating; then placing it on the table in order to pick up the cup of milk with both hands, one hand holding the handle of the cup, while the other supported the side of

the cup. No consistency was noted in the function assumed by either hand, as the convenience of the situation apparently determined that factor. Thus, when the cup had been so placed before the child by the server that the handle was at the right, the right hand of the child held the handle while the left hand supported the side. When the cup had been so placed by the server that the handle was at the left, then the left hand held the handle while the right hand supported the side. On no occasion was the child observed to turn the cup so that the handle was at the side opposite to that at which it had been placed.

(3) Holding the cup by the handle with the right hand and holding the cracker in the left hand, alternately eating and drinking. This method was used by two of the four-year-olds. The cup had been so placed by the server that the handle was at the right.

(4) Holding the cracker in the right hand; then passing it to the left hand in order to pick up the cup with the right hand, and then alternately eating and drinking. This was noted on one occasion only, in the performance of one child.

(5) Holding the cracker in the right hand, and picking up the cup,—which was so placed that the handle was at the right—by the side with the left hand. This was noted on one occasion as one method used by Subject R during a short part of one period of observation.

Subjects C and D, two-year-olds, were each observed in the act of handing an object to another child. At the time of the observation, subject D was holding a piece of plasticine in each hand. Another child asked her for a bead which was on the table nearby. Subject D relinquished the piece of plasticine which was in her right hand, and reached for the bead and passed it to the second child with that hand. Subject C at the time of observation was holding a hammer in his right hand, when another child in the group dropped a bead, which rolled toward the right of C. C put down the hammer and picked up the bead with the right hand, passing it to the child with that hand.

In the four-year age group, one child, subject N, was observed in handing objects to others. He had picked up a book with the right hand, placing it under his right arm. He then picked up several others with the unoccupied left hand and placed them also under the right arm. He went around shouting "books for sale;" and distributed them to purchasers, passing them with the unoccupied left hand.

Wiping the table, floor, or blackboard, was noted in the performance of one or more subjects in each of the three age-groups. When both hands were unoccupied, all of the children observed used the right hand; however, when the right hand was occupied, there was some variation in individual performance. Subject D on the three occasions noted, put down the article which she held in her hand in order to secure the cloth and wipe up the water from the floor or table. Subject N, on one occasion, while holding in his right hand a piece of chalk with which he was drawing on the blackboard, reached with the left hand for the cloth and wiped out the drawing with the cloth held in that hand. Subject O, under the same condition, picked up the cloth with the right hand while holding the chalk in that hand, and wiped the drawing from the blackboard with both cloth and chalk in his right hand.

Pulling a wagon was performed by two subjects, G and I, on one occasion each. Subject I used the right hand during the short period in which he engaged in this activity. Subject G alternated in the use of the hands.

Drawing with chalk on the blackboard was observed in the performance of one subject in the three-year group and six subjects in the four-year group. This activity was invariably performed by all subjects with the right hand. When a crayon of a color different from the one in use was desired, sometimes the subject would first dispense with the piece he was holding and reach into the box or on the ledge for the new piece, with the right hand. Sometimes the subject would reach with his unoccupied left hand for the new piece, immediately releasing the first piece which he held in the right hand, and transferred the second piece to the right hand for manipulation.

The peg board was noted in the activities of the two-year-olds only. The two subjects observed, B and D, differed in type of manipulation, and in degree of bias for their "preferred" right hand. Subject D consistently used her right hand for both picking and placing the pegs regardless of the position of the box containing the pegs—that is, whether the box was at her right, at her left, or directly in front of her. In five periods of observation, during which a total of 100 pegs were placed, only 3 or 4

were placed by D with the left hand. Subject B, on the other hand, varied his manipulation in different trials, and also within the same trials. When the box of pegs was at his right, he picked and placed all but a few with the right hand, picking the remainder with the right hand, but placing them with the left. When the box of pegs was at his left, he picked all of the pegs from the box with the left hand and passed them to the right hand to place in the peg board.

Block building was observed in all three age-groups, although it occurred more frequently in the three-year group than in either the two-year or the four-year group. During the course of a single observation, the method of manipulation was sometimes unimanual, one hand picking and placing the blocks, and at other times bimanual, one hand picking the blocks and the other hand placing them. Manual choice in block building seems to be influenced by various factors, such as, the location of the blocks with reference to the child, and the direction in which the child is building. The direction in which the child is building appears to be influential under conditions when extreme right or left is involved. When the blocks were at the right of the subject, the right hand was almost invariably used to pick the blocks, and usually used to place them; however, when the child was building toward the left, the blocks were frequently passed from the right hand to the left hand for placement, particularly those which were designed for the extreme left of the building or railroad track under construction. When the blocks were at the left of the child, the tendency on the part of the majority of the children observed was to pick them with the left hand and pass them to the right hand for placing, unless the direction of building was toward the extreme left, when the left hand also placed the blocks. There was some variation with respect to the blocks lying at the left. For example, subject K would use the right hand to pick and place the blocks, regardless of whether they were lying at his right or at his left, except that in placing the blocks at the extreme left of the structure erected he would use the left hand. Subject J, on the other hand, would use the right hand to pick and place the blocks lying at his right, and would use the left hand to pick and place those lying at

his left, except when building to the extreme right or extreme left, when the "convenient" hand would be used to do the placing. When the blocks were at the front of the child, the usual method was to alternately pick and place a few with the right hand, then a few with the left, apparently showing no definite preference for either hand.

II. Bimanual-1 acts. In activities such as drawing with crayon on paper; writing; painting; brushing over cubes of paint; swirling a brush about in a jar of water; stamping numbers on paper with a rubber stamp; cutting out pictures, numbers, or designs, with a pair of scissors; brushing over cut-outs with a paste brush, and fastening them to a cardboard or other background; manipulating plasticine as an object worked upon by another tool; sandpapering blocks or other wooden objects; manipulating implements, such as a saw, hammer, chisel, vise, screw driver: in all of these activities in which the hands coöperate simultaneously to effect the completion of a total situation, and in which the function of the two hands is different in kind and degree, the right hand was invariably used by all of the children in all three age-groups for the active, major part of the performance, and the left hand was invariably used for the relatively passive, accessory function. Thus, the right hand was consistently used to manipulate the crayon, the pencil, the paint brush, as the left hand rested on the paper, held the object which was being colored, supported the jar of water as the brush was being swirled about in it, or held the cube of paint on the table as the brush was passed over it. The right hand was used to manipulate the rubber stamp as the left hand held the stamp pad, or rested on the paper upon which the numbers or letters were pressed; the right hand manipulate the scissors as the left hand held the paper; cut slices off the ball of plasticine with a tiny board as the left hand held the plasticine down on the work table; brushed over cut-outs with the paste brush as the left hand held the cut-out steady to prevent slipping; manipulated the sandpaper as the left hand held the blocks or supported the side of a box which was being smoothed; wielded the hammer, saw, chisel, vise, screw driver, as the left hand supported the board which was being sawed or pried apart, or held the nail which was

being driven into the board. Occasionally subjects J and K would use both hands simultaneously for a short time in hammering. Subject J held the right hand at the top of the handle and the left hand down near the hammer, whereas subject I held the hands in reverse fashion. The chisel and small screw driver were used occasionally, not as tools with which active work was performed, but as objects on which activity was exerted. For example, subject F one day held the chisel against a board and hammered down upon the chisel in an endeavor to split the board. The screw driver was used in the same way by subject G. Under these conditions, the chisel or screw driver was held down on the table or board by the left hand, as the right hand wielded the hammer upon it.

Subjects G, F and I in the three-year group, and subject P in the four-year group were observed while picking little pins with celluloid tops of different colors from tiny boards, and sticking the pins into a beaver board. Subjects G and P each consistently used the right hand in picking the pins from the tiny boards and in sticking them into the beaver board, regardless of the position of the box which contained the tiny boards. When the box containing the boards was at the left of either of these subjects, he would take a board from the box with the left hand and hold it in that hand as he picked the pins from it and placed them with the right hand; and when the box was at the right, each of these subjects would pick the board from the box with the right hand, and pass it to the left hand to hold, as the right hand did the active manipulating. Subject F, in the one performance noted of this activity, would reach over with his right hand and take a tiny board from the box, which was at his left; and, holding it in the right hand, he would remove the pins from it and stick them in the beaver board with the left hand. Subject I, with the box of boards in front of him, would take up a board with the left hand, and while holding it in that hand, would remove the pins therefrom and place them in the beaver board with the right hand. After a short while he would reverse the procedure, taking up the board from the box with the right hand, and while holding it in that hand, remove the pins and place them in the beaver board

with the left hand. Thus it appears that individual variation was shown in this activity.

Four three-year-olds and three four-year-olds were observed on one or more occasions in carrying a painting or drawing which they had completed, from their work table to the display wall, and pinning it to the burlap stretched on the wall for that purpose. Sometimes a subject would pick the picture up from the table with the right hand, after laying down the paint brush or crayon which he had been manipulating with that hand, and would carry the picture to the wall in the right hand. Then the picture would be transferred to the left hand and held against the burlap with that hand, as the subject reached for a pin with the right hand and pinned the picture to the burlap with the right hand. Sometimes a subject would pick the picture up from the table with the unoccupied left hand before laying down the paint brush or crayon which he had been using with the right hand, and would carry the picture to the wall with the left hand. Under this latter condition, all of the subjects observed with the exception of subject I would then hold the picture against the burlap with the left hand, and reach for the pin with the right hand, and pin the picture to the burlap with the right hand. Subject I, however, on two occasions carried the painting to the burlap with the left hand, then transferred it to the right hand to hold against the wall, as he reached for the pin with the left hand and endeavored to pin the paper to the burlap with that hand. Failing in the attempt, he transferred the paper again to the left hand to hold against the burlap as he pinned it with the right hand. On the third occasion, he immediately held the paper against the wall with the left hand as he reached for the pin with the right hand and pinned the paper to the burlap with that hand. In the fourteen observations recorded of this activity, success was finally achieved in all cases by holding the paper against the burlap with the left hand, and pinning it thereto with the pin held in the right hand. While reaching for the pin was a task which could apparently be achieved by either hand, pinning the paper to the wall seemed to call for the use of the right hand.

Peg board activity and playing with blocks were treated in the

section dealing with unimanual activities, as the method of manipulation in each of these varied from unimanual to bimanual within the performance of a given individual in the same period of observation. Stringing beads was not performed by any of the subjects in the right-handed group.

III. Bimanual-2 acts. In carrying objects such as a jar of water or a cup of milk, a subject would occasionally use both hands, each hand supporting a side of the jar or the cup. Sometimes the handle of the cup would be held by one hand and the side of the cup would be supported by the other. In all cases observed, the hand which held the handle of the cup was the one conveniently located with reference to the handle. On no occasion was a child observed, while carrying a cup of milk or conveying it to the mouth, to turn the handle of the cup around so that it might be held by the preferred hand.

Moulding of plasticine was noted in all three groups. The two-year-olds favored primarily the bimanual-1 method, in which the plasticine was held on the table by the left hand, while the right hand cut slices from the ball of plasticine with a tiny stick, or dug holes in it with the stick. The three-year-olds and four-year-olds occasionally manipulated the plasticine in this manner, however they favored the bimanual-2 method of moulding the plasticine, in which both hands participated in the kneading and forming. Preferential use of either hand in degree of functioning was not observed.

Sweeping was performed by 3 subjects in the three-year group and by 2 in the four-year group. Each of these children held the right hand at the top of the broom handle, and the left hand about half way down the handle.

Left-handed subjects

I. Unimanual acts. In unimanual acts such as picking up objects which had fallen, and picking up and carrying objects required in manipulation, the two left-handed subjects showed some difference in performance. Ff was nearer the right-handed children in that she frequently used the right hand to pick up objects which were equally accessible to either hand, and when neither

hand was occupied. In securing objects from the supply table for use at her own work table, she usually picked up one with the left hand, then a second object with the right hand. On the one occasion when she was observed pulling a little cart, she held the string first by the right hand, then by the left hand. These were the only unimanual activities in which Ff participated.

Subject Ee decidedly favored the left hand in picking up objects which had fallen, carrying supplies to his work table, wiping up spilt water from the table with a cloth, regardless of whether the left hand were occupied or not. In carrying objects to his work table, he usually carried one at a time, using the left hand, although he occasionally carried one in each hand.

When serving milk to the children in his group, subject Ee picked up and carried each cup by the left hand, sometimes by the handle, sometimes by the side, unsupported by the right hand. In picking up the cups from the table at which the children had been eating, he used the left hand exclusively; however, when a child passed him the cup with the right hand, he would accept with his right hand and carry the cup back in that hand.

Subject Ee was observed during two lunch periods. He would hold the cup in one hand and the cracker in the other hand, occasionally changing hands, so that the hand which had been holding the cracker held the cup, and the hand which had been holding the cup now held the cracker. He did not, on any occasion noted, turn the cup around so that the position of the handle would be changed.

On the two occasions when Ee drew on the blackboard, he used the left hand exclusively.

Block building, as in the case of the right-handed children, was sometimes unimanual and sometimes bimanual. When unimanual, the left hand predominated in use. When bimanual in nature, the function of the hands was determined, as in the right-handed group, by factors of convenience, such as the direction of building.

II. Bimanual-1 acts. In activities such as drawing with crayon on paper; painting; brushing over cubes of paint; swirling a brush about in a jar of water; cutting out pictures, numbers,

or designs, with scissors; brushing over cut-outs with a paste brush, and fastening them to a cardboard or other background; manipulating plasticine as an object worked upon by a tool; sandpapering blocks or other wooden objects; manipulating implements, such as a saw, hammer, chisel, vise, screw driver: in all of these activities in which the function of the two hands is different in kind and degree, the left hand was invariably used for the active, major function, while the right hand was used for the relatively passive, accessory rôle. On one occasion only did subject Ee use the right hand for the active, major rôle, while the left hand performed the minor rôle; and that was in the use of a saw, when the board had been clamped on to the bench by the Director of the Institute in such a way that the use of the saw with the right hand was the only possible method. Ee used the saw with the right hand for a while, then used both hands simultaneously.

Ee and Ff were each observed on several occasions while pinning a picture to the burlap. Each of these subjects on one occasion, after having carried a painting from the work table to the wall with the left hand, held the picture against the burlap with the left hand, and after securing a pin with the right hand, attempted to pin the picture to the burlap with the right hand. Failing in the attempt, the subject transferred the pin to the left hand and the paper to the right hand and succeeded in pinning the paper to the burlap with the left hand. On all other occasions, however, each of these subjects held the paper against the burlap with the right hand, regardless of which hand had carried it over, and reached for the pin and fastened the paper to the burlap with the left hand.

Playing with blocks was noted in the unimanual section, as the method used in this activity varied from unimanual to bimanual in the performance of a single period. Writing, stamping numbers on paper with a rubber stamp, placing pins in a beaver board, pegging, and stringing beads were not noted in the periods of observations of either of these subjects.

III. Bimanual-2 acts. Carrying objects, lifting a cup of milk to the mouth, and serving milk, have been noted in preceding sections. As these acts were, within the course of a single obser-

vation, sometimes performed as unimanual and sometimes as bimanual activities, it is more convenient to treat them together.

Plasticine was kneaded and moulded and rolled by both hands functioning coöperatively.

Sweeping was performed by subject Ee only. Contrary to the manipulation of the right-handed children, this subject held the left hand at the top of the handle, and the right hand half way down the handle.

Ambidextrous group

1. Unimanual acts. In the performance of unimanual acts such as picking up objects and carrying objects, when both hands were unoccupied and the object to be grasped was equally accessible to both hands, none of the subjects used a given hand exclusively. Some variation in preferential usage, however, was shown, as subjects Cc and Kk each used the left hand more frequently and subject Jj used the right hand more frequently, under these conditions. When, however, convenience was a factor, manual choice was affected accordingly. If the right hand were occupied, the left hand was usually used to secure a desired object; or, if the desired object were nearer one hand than the other, the convenient hand was used.

Subjects Cc and Kk were each observed in picking up a cloth and wiping the floor. The hand favored by the convenience of the situation was the hand used by each of these subjects in one performance of this activity. Thus, Cc picked up the cloth, which was lying to the right of her, with the right hand and manipulated it with that hand for a while. In accordance with her usual custom, she soon transferred it to the left hand for a short time, then back to the right hand again. Subject Jj, while holding a paint brush in the right hand, secured the cloth with the unoccupied left hand and wiped the floor. On a second occasion, although both hands were unoccupied, he picked up the cloth with the left hand and manipulated it. On both of these occasions, however, he soon transferred the cloth to the right hand for action; then later back to the left hand again.

Subjects Cc and Kk were each observed during one period in

pulling a little wagon. Each subject held the string first in the left hand, then transferred it to the right hand.

While pulling the little wagon by the string which she held in her left hand, Cc "sold" the director of her section a block of wood, holding out her unoccupied right hand to receive the bit of paper which passed for money, before delivering her wares. Grasping the money in her right hand, she dropped the string which she held in the left hand, and picked up a block of wood from her cart and handed it to the director with the left hand. During another period of observation, Cc picked up a box of beads with her left hand, and with the unoccupied right hand picked the beads out of the box one by one and handed them to the rest of the group. The hand used in handing objects to others was apparently determined by the convenience of the situatuion.

Cc alternated in the use of her hands, not only in pulling a wagon, and in wiping the table and floor, but also in picking up and conveying to her mouth the pieces of cracker which she had crumbled with her left hand while holding it in her right hand, and in picking and placing pegs during a period of unimanual operation. But one observation was made of Cc in holding a cup of milk. The cup had been so placed by the director that the handle was at C's right. She picked up the cup by the handle with the right hand, occasionally supporting the side with the left hand.

Subjects Jj and Kk were each observed during one period in building blocks. The performance of each of these subjects was unimanual in type, and ambidextrous. That is, one hand would both pick and place the blocks; however, the hands were used alternately. Convenience apparently operated to some extent in determining the favored hand.

Subject Jj threw a rubber ball through a steel hoop into a cloth bag fifteen times in succession on one occasion, using his right hand in all throws, although he was informed by the observer that he might use either hand. He seemed to derive great joy in the activity, and stated that he often played ball with his father.

II. Bimanual-1 acts. The three subjects in this group differed

considerably from each other in the performance of bimanual-1 acts observed during the course of this study. The two-year old, subject Cc, and one of the four-year olds, subject Kk, were nearer each other in type of manipulation than were either of them to subject Jj. Both Cc and Kk used the hands interchangeably for the major part of such activities as drawing with crayon on paper, painting, brushing over cubes of paint, swirling a brush about in a jar of water, cutting out pictures or designs with a pair of scissors, manipulating plasticine as an object worked upon by a tool, manipulating the hammer. Each of these two subjects favored first one hand, then the other, with the major or active part of these activities, the hand not so favored at a given time performing the relatively passive but accessory part of the total act. These two subjects differed, however, in that Kk apparently favored neither hand more than the other in any of the activities noted, whereas Cc favored the right hand to a greater extent than the left in performing the active rôle in drawing, cutting pieces of plasticine off of the ball with the little wooden slab, and in manipulating the scissors; and favored the left hand primarily in the active rôle in hammering.

Subject Jj alternated in the use of his hands for the major part of such activities as drawing and writing his name. The hand used in the major part of these activities was not apparently determined by the hand with which he picked up the tool. Sometimes he would pick up the pencil with the left hand and write or draw with that hand for a while, then transfer the pencil to the right hand for manipulation. Again, he would pick up the crayon or the pencil with the right hand—particularly if it were more accessible to that hand—and transfer it to the left hand for manipulation; shortly thereafter passing it to the right hand for use. Throughout a single observation he would alternate several times in the use of the hands. In drawing circles, Jj moved the pencil counter-clockwise, regardless of which hand was performing. In writing, Jj wrote both the normal left to right and the reversed direction, right to left, and used both methods with either hand. His letters, when written in the reversed direction, were likewise reversed. Two observations were made of his writing, the obser-

vations being about a week apart. His first name was written four times, and his last name twice. The first name was written three times by the left hand, in reversed letters, from right to left. The fourth time, the left hand started to write the first name in normal fashion, from left to right, but when half through, the pencil was transferred to the right hand for completion of the task. During one observation the last name was written in reversed fashion, from right to left, the right hand starting the performance, but when half the letters were formed, the left hand took over the task and completed it. On another occasion, Jj started to write his last name in reversed fashion with the left hand, and when half way through, put down his pencil, stating that he did not know what came next. The observer wrote his name in full with the pencil held in her right hand, writing in normal left to right fashion. He again picked up the pencil with the left hand and copied from her sample, writing, however, in reversed fashion.

In the use of the vise, also, Jj sometimes alternated in the use of the hands, first using the right hand for the major part of the performance and the left hand for the accessory rôle; then reversing the hands. However, in hammering, sawing, and in the use of the scissors and paste brush, the right hand was used exclusively for the major function, the left hand performing the accessory role. This method was followed regardless of which hand picked up the tool with which the activity was to be performed. Thus, once or twice the hammer was picked up by the left hand, and a nail by the right hand. The nail was transferred to the left hand and held down on the board, as the hammer was transferred to the right hand for active use.

Although subject Kk was six months older than subject Jj, he was far inferior to Jj in extent and quality of manipulation, as well as in general intelligence. While a greater variety of activities is listed for subject Kk than for subject Jj, the latter was by far the more active of the two. He would persist longer in a given activity, and focus his attention upon it, thereby accomplishing something. He was particularly fond of writing and of drawing. Kk, on the other hand, spent the major part of his time listlessly watching other children, wandering from one activity to another, and being relatively inactive most of the time.

Summary. A series of daily observations made on a group of pre-school children for the purpose of ascertaining the preferential use of the hands in daily uncontrolled activities, and of determining the consistency of such manual preference in repeated performances of any given activity, indicated the following facts:

Comparatively few of the types of activities observed were invariably unimanual in nature. Some of the activities observed were at times unimanual and at times bimanual in nature. The bimanual method of manipulation assumed two forms, in one of which the function of the two hands was the same in kind, and in the other, the function of the two hands differed in kind. The majority of the acts performed were of this latter type, in which one hand performed a major function, and the other hand aided in the performance of a relatively minor, accessory rôle.

There are certain activities which seem to lend themselves to a consistently preferential manipulation, activities in which it is preferable to cultivate efficiency by automatic action; whereas there are other activities in which the use of either hand can frequently be adopted, activities of such a nature that the situation itself determines which hand will be used. This differentiation is apparently made at a very early age; in fact, it was apparent in the performance of the four children below the age of three years who were observed in this study.

Thus, a consistency of manual choice was shown by all of the children observed, except three ambidextrous subjects, in the performance of one strictly unimanual act, namely, drawing with chalk on the blackboard, and in the major part of many so-called bimanual acts. In drawing with a crayon on paper, in writing, painting, brushing over cubes of paint, cutting out pictures with scissors, sandpapering blocks, manipulating implements such as a saw, hammer, chisel—in all of these activities, the children who had been termed right-handed by their parents invariably used the right hand for the active, major part of these performances, giving to the left hand the minor rôle. The children who had been designated left-handed by their parents invariably favored the left hand for the active, major part of these performances, using the right hand as an aid in the performance of the

minor, accessory function in the total situation. Only in the performances of the three children who, according to the report of their parents, were ambidextrous, was variation in the function of the two hands shown in these activities. These three children at times favored the right hand with the major rôle, and at times favored the left hand with that rôle. Varying degrees of ambidexterity were noted in the performances of these three children, however, as two of the subjects used the hands interchangeably in all activities, while one subject used the hands interchangeably for the major rôle in writing and drawing, but in other activities he approximated the performance of the right-handed children.

A certain degree of variability in manual choice was shown in the performance of practically all of the children in such unimanual acts as picking up objects, carrying objects, passing objects to others, wiping the floor or blackboard, pulling a wagon, block building, and placing pegs in a peg board. The factor of convenience apparently determined, to some extent, the hand used in these activities. Thus, in reaching for and picking up objects equally accessible to either hand, when both hands were unoccupied the children termed right-handers by their parents almost invariably used the right hand, and those termed left-handers almost invariably favored their left hand. However, when the "preferred" hand was occupied, or when the desired object was more conveniently located with reference to the non-preferred hand, the hand thus favored by circumstance was usually favored by the child.

General Summary

Convenience apparently plays an important rôle in the preferential manipulation of pre-school children in activities of certain types. In picking up and placing objects, in such activities as the marble board and the form board, when the objects of manipulation were equally accessible to either hand, a pronounced tendency was shown by the subjects in both the Right-handed and Left-handed groups, to use the hand preferred in daily activities, termed the "preferred" hand. When these objects were con-

veniently located with reference to the "preferred" hand, this tendency toward the use of the "preferred" hand was pronounced to an even greater extent, its use being practically exclusive by the subjects in both groups. When, however, the objects of manipulation were so located as to offer a convenience to the use of the "non-preferred" hand, but an inconvenience to the use of the "preferred" hand, considerable variability in degree of bias for the "preferred" hand was manifested by the subjects in both handedness groups.

These same tendencies were noted on the part of the children in both groups in an activity which involved running from a starting point to a desired object, and reaching for and grasping that object, under conditions calling for rapid, spontaneous choice of hand. The tendency toward the use of the "preferred" hand was pronounced on the part of the majority of the children in both handedness groups in this activity. Analysis of position assumed by the subject with reference to the desired object, after running from the starting point to that object, indicated that the factor of convenience seemed to operate here also. Thus, when the position assumed was on the side corresponding to the "preferred" hand, a pronounced tendency toward the use of that hand was noted in both handedness groups. When the position assumed by the subject was center, thus rendering the object equally accessible to either hand, there was likewise a tendency toward the use of the "preferred" hand in both groups, although in the Right-handed group this tendency was not as marked as when the position assumed was at the side corresponding to the "preferred" hand. When the position assumed by the subject was at the side opposite to that of the "preferred" hand, thus rendering the object of manipulation more accessible to the "non-preferred" hand, there was considerable variation in extent of preference for the habitually "preferred" hand in both handedness groups, some children favoring the "preferred" hand primarily, some showing marked favor for the "non-preferred" but convenient hand, and some showing no marked preference for either hand.

In situations where two desired objects of the same type, placed

in proximity to each other, were to be secured under conditions calling for rapid, spontaneous choice of hand, the young child showed no specialization in the use of the hands, using one hand to reach for the object and the other to hold it, nor did it favor either hand to any extent in point of time; but the hands functioned in the most efficient, convenient manner under the circumstance, as the method of manipulation primarily employed was that of reaching for and grasping an object with each hand simultaneously.

No consistent relation was shown between position assumed by the subject with reference to a desired object after running from the starting point, and manual "types," that is, the habitually right-handed or left-handed child. Relatively few of the subjects in either of the handedness groups assumed a given position in all trials, when running from the starting point to the basket containing the objects to be seized. However, when a single object was the stimulus, the majority of the subjects in the Right-handed group showed a marked preference for the position to the right of the object, while the subjects in the Left-handed group favored primarily the center position.

An inverse relationship was evident in the performance of all subjects between the position assumed with respect to the object seized, and direction of orientation by the subject after the desired object had been secured. When the position assumed was at the right, the direction of turn was practically invariably toward the left; and when the position assumed was at the left, the direction of turn was almost invariably toward the right.

No consistent relation was shown between direction of orientation by the subject after the desired object had been secured, and manual choice; nor was any consistent relation evident between direction of orientation and manual "types."

While none of the children in either the Right-handed or the Left-handed group used the "preferred" hand exclusively in all trials of the three tests in preferential manipulation given them, the majority of the children in both groups showed a strong bias for their "preferred" hand in all tests except in that section of the form board test in which an inconvenience was imposed on the use

of the "preferred" hand. There was some individual variation, however, in that a few children in each group used their "preferred" hand primarily under all conditions, even when an inconvenience was imposed upon its use; and a few children showed no preference for their habitually "preferred" hand in a test or portion of a test in which inconvenience to the use of that hand was not involved. Thus, the results of these various tests of handedness seem to indicate the existence of "degrees" of manual bias, ranging from a pronounced preference for either the right hand or the left hand, to a relatively ambidextrous state in which neither hand is definitely favored, or in which the hand "convenient" under the circumstance is favored. The two manual types designated conventionally as "right-handed" and "left-handed' apparently indicate "trends" rather than two distinct classes, at least in so far as activities of the type used in these tests are concerned. Since factors of convenience apparently predispose to the use of the "convenient" hand—practically exclusively when the convenient hand is also the habitually preferred hand, and to varying extent when the convenient hand is the non-preferred hand—it might be that the nature of manual choice under conditions offering equal opportunity for the use of either hand, as in the marble board test, is diagnostically more significant in ascertaining these "trends" than is the nature of choice when objects are conveniently located with reference to one hand but inconveniently located with reference to the other. A test of the type of the form board, given under conditions obtaining in this study wherein a convenience was offered to the use of the "preferred' hand in the manipulation of the forms lying on one side of the board, but an inconvenience was offered to that hand in the manipulation of the forms lying on the other side of the board, seems to provide a method of ascertaining the "degree" of manual bias. An activity such as the picking-up-toy test, in which the subject runs from the starting point to the desired object, thus permitting the occurrence of a variety of fluctuating environmental conditions which may operate to influence manual choice, does not seem as adequate a means of ascertaining either the "trends" or the "degrees" of preferential handedness as do the

marble board and the form board respectively, in which these environmental conditions are controlled.

Improvement in speed of performance by the "non-preferred" hand in a practice series in pegging was shown by a group of right-handed children, ranging in age from 3 years to 5 years. Improvement was also noted in this group in the performance of the unpracticed right hand after the practice series by the "non-preferred" left hand, as compared with the performance of the right hand prior to the practice series, suggestive of transfer of training. The performances of the majority of the children in the left-handed group did not show a marked tendency toward improvement in either the practiced right hand or the unpracticed left hand, although there was some individual variation. Many factors were noted which render difficult a study of learning in children through speed of performance.

Training of strongly left-handed children of pre-school age in the use of the right hand in motor activities involving gross muscle coördination as well as those involving the finer muscle coördinations, seems possible. Individual differences were noted with respect to the following: (1) extent of learning as measured by accuracy of performance, (2) attitude of the subject toward the use of the "non-preferred" right hand, and (3) presence of observable tension in the relatively unoccupied left hand and in the face of the subject. This tension existed during the early part of the test series, and was noted to gradually decrease, and apparently disappeared completely after a few days of testing. Improvement was manifested earlier in the test involving primarily the gross motor coördinations, than in the test involving the finer motor coördinations.

Daily observations of the preferential use of the hands by children of pre-school age in activities of their own choice indicated the following significant facts:

(1) Comparatively few of the types of activities performed were invariably unimanual in nature. The majority of the acts were bimanual, of the type in which one hand performs a major function, and the other hand aids by the performance of a relatively minor, accessory rôle.

(2) There are certain activities which seem to lend themselves to a consistent preferential manipulation, activities in which it is preferable to cultivate efficiency by automatic action; whereas there are other activities in which the use of either hand can frequently be adopted, activities of such a nature that the situation itself determines which hand will be used. This differentiation is apparently made at a very early age; in fact, it was apparent in the performance of the four children ranging in age between 2 years 4 months and 2 years 9 months, who were observed in this study.

Thus, a consistency of manual choice was shown by all of the children observed in this study, except three ambidextrous subjects, in the performance of one strictly unimanual act, namely, drawing with chalk on the blackboard, and in the major part of many so-called bimanual acts. In drawing with a crayon on paper, in writing, painting, brushing over cubes of paint, cutting out pictures with a scissors, sandpapering blocks, manipulating implements such as a saw, hammer, chisel—in all of these activities, the children who had been termed right-handed by their parents invariably used the right hand for the active, major part of these performances, giving to the left hand the minor rôle; whereas the children who had been designated left-handed by their parents invariably favored the left hand for the active, major part of these performances, using the right hand as an aid in the performance of the minor, accessory function in the total situation. Only in the performances of the three children who, according to the report of their parents, were ambidextrous was variation in the function of a given hand shown in these activities, the right hand performing the major function at times, the left hand performing that rôle at other times.

On the other hand, a certain degree of variability in manual choice was shown in the performance of practically all of the children in such unimanual acts as picking up objects, carrying objects, passing objects to others, wiping the floor or blackboard, pulling a wagon by a cord, block building, and placing pegs in a peg board. The factor of convenience apparently determined, to some extent, the hand used in these activities.

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THE SIGNIFICANCE OF DELAYED REACTIONS IN YOUNG CHILDREN

BY

MAGDA SKALET

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THE SIGNIFICANCE OF DELAYED REACTIONS IN YOUNG CHILDREN[1]

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Research Associate, Brush Foundation, Western Reserve University

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[1] A dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy.

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I. HISTORICAL SUMMARY OF THE LITERATURE

Introduction. Before commencing a discussion of the experimental methods and the results of the present investigation of delayed reactions in young children, a critical survey will be given of the experimental literature pertaining to the processes involved in these reactions. A delayed response is one in which the determining stimulus is absent at the moment of response. The essential part of the situation is that memory of some particular part of the stimulus pattern is necessary for a correct response when the original determining stimulus is absent. Not only memory, but attention, learning, and perception of form and location are inextricably involved in the test situations formulated by the investigators in this field. There is marked disagreement among these authors as to the nature of the representative

factors that act in place of the original stimulus and in analyzing the various processes included. Very few of them recognize the multiplicity of elements in a single delayed response.

Animal experimentation. For comparative purposes, a summary of the quantitative results of the investigations on delayed

TABLE 1

The length of delay obtained with various animals

SUBJECTS	NUMBER	DELAY	NUMBER OF ALTERNATIVES	BODILY ORIENTATION	EXPERIMENTER
Rats	1	15 seconds	3	With	Hunter (8)
	12	40 seconds	3	With	Ulrich (18)
Cats	8	18 seconds	2	With	Yarbrough (21)
	1	30 seconds	2	Without	Cowan (5)
	8	4 seconds	3	With	Yarbrough (21)
	2	16 hours	4	Without	Adams (1)
Dogs	2	5 minutes	3	With	Hunter (8)
	2	1 minute	4	Without	Ulrich (18)
Raccoons	4	25 seconds	3	Without	Hunter (8)
Monkeys	4	15–20 hours	2	Without	Tinklepaugh (17)
	2	56 seconds	3	Without	Rugh (25)
Chimpanzees	1	15 seconds	?	Without	Kohts (16)
	2	16½ hours	Buried food	Without	Köhler (13)
	4	48 hours	Buried food	Without	Yerkes and Yerkes (25)
	4	4 hours	4	Without	Yerkes and Yerkes (25)
Gorilla	1	?	5	Without	Yerkes (22)
	1	48 hours	Buried food	Without	Yerkes (23)
	1	3 hours	4	Without	Yerkes (23)
	1	10 minutes	6	Without	Yerkes (24)

reactions in animals reported in this chapter is given in table 1. A large portion of this table is taken directly from Tinklepaugh (17), and the remainder from the original reports not given in this article. The number and kinds of subjects employed, the maximum length of delay for securing accurate responses, the

number of alternatives offered, the presence or absence of bodily orientation, and the name of the experimenter are included in the table. It must be remembered when referring to this table, that the length of delay possible with one experimental method is not comparable to that obtained by another method. Many of the investigators do not state that the delay obtained is the maximum for that animal with the type of situation used, but do set forth the maximum periods of delay obtained in the reported experiments.

Since Hunter (7) formulated and conducted the first extensive experiments on delayed reactions, and since these served as a pattern for the majority of the later research, his procedure and results will be reviewed in some detail. He attempted to discover how long after the determining stimulus had disappeared the subjects could wait and still react correctly, and to analyze their typical behavior in solving the problem.

Hunter's subjects consisted of 22 rats, 2 dogs, 4 raccoons, and 5 children who were from two and one-half to eight years of age. The light boxes developed for the experiments were essentially the same for all three kinds of animals included, differing only in absolute dimensions. The children were tested in a suitably arranged room instead of a box-like apparatus. Before the animals used could respond accurately, Hunter found it necessary to give them a training series. The food-light box association was learned, then several succeeding trials were given in which the light was turned off before the animal was released from the confining compartment.

According to Hunter, this apparatus and procedure has all the necessary features for the measurement of delayed reactions, for it is adapted to the subjects, it provides a means for presenting the stimulus in one of several places which are equally accessible, and no differential cues can be presented to the subject during the period of delay.

White rats succeeded in running in the proper direction when the delay between the disappearance of the light and their release was not more than 10 seconds, but only in case they maintained their orientation towards the light during the interval. Rac-

coons, on the other hand, although they could not go in the right direction if more than 25 seconds had elapsed since the light was turned off, succeeded in this interval whether they did or did not change the positions of their bodies. Dogs could make accurate responses after an interval of five minutes when they retained their positions with respect to the stimulus shown.

Watson (20) criticizes Hunter for inadequate control of the situations in these experiments. He asserts that cues given by the experimenter, perception of temperature differences in the most recently lighted box, the odors of food, and certain visual effects of the light might plausibly lead to the correct response. Hunter (8) refutes each of these possibilities by pointing out the results obtained in control experiments, and from the observations of the animals during the delay intervals.

Hunter's results (7) indicate that the following factors influence the maximal period of delay: different groups of animals, the size of the release, and the number of light boxes used. He concludes that punishment and reward, the number of trials daily, and the varying brightnesses of the different backgrounds do not materially affect the amounts of the delay. The correct response occurs because the residual effects of the sensory stimuli are retained and are subsequently re-aroused. The selective revival of these stimuli functions as a necessary substitute for a definite component of the objective stimulus aspect of the problem.

Several investigators have used apparatus constructed according to Hunter's design. Ulrich (18) studied the posturing of rats in connection with delayed response. He found that there was a definite direction in the rat's progress only when there was orientation, a series of forward movements, or scratching at a certain part of the retaining chamber. His rats responded correctly after an interval of 40 seconds. It has been shown by Yarborough (21) that cats also depended for success in responding to light and sound stimuli, upon the maintenance of a fairly constant bodily orientation during the delay interval. The maximum interval obtained giving a correct response was 18 seconds with the use of two alternatives, and 4 seconds when three were

employed. Walton (19) secured correct reactions from dogs in two-thirds of the trials using four compartments and a delay of one minute during which the cage containing the dog was turned through 90 degrees; thereby, totally disturbing the dog's position in the cage. When two compartments were used, considerably longer delays were possible, and although various disturbing olfactory, visual, and auditory stimuli were introduced during the delay period, they produced little effect. Rugh (16) obtained a maximum delay of 56 seconds with two monkeys; above this point the responses were purely chance.

The chief criticism of Hunter's method and its modifications as given by Buytendijk (4), Köhler (11), and Tinklepaugh (17), is that the experiments require for their solution, superficial accustoming and experience on the part of the subjects, since they do not afford any natural connections comprehensible to the animals. According to these authors, this apparatus is not adequately adapted to the subjects. Several experimental situations have been set up differing from that used by Hunter (7) with the animals in that the primary motivational control was more direct.

Yerkes (22) placed five brass boxes, two inches apart on a board, equipped with hinges so that they could be thrown back, and provided them with electrical connections for giving a shock if this was desired. In none of the 15 trials when the food was placed in one of these boxes did the gorilla make a correct first response after a one minute delay. In an attempt to train the gorilla always to choose the middle object, 80 trials were insufficient for her to achieve the idea of middleness. A satisfactory response in this case would involve both memory and learning. Yerkes concludes from these data that he evidently failed to properly relate and control reward and punishment and thus discouraged the subject, but the experiments demonstrate the applicability of electrical stimulation for supplying negative motivation to the gorilla.

Due to the inadequacy of this procedure, while working with this same gorilla the next year, Yerkes (23) arranged four boxes (white, red, black, and green, with closely fitting but unhinged

lids) around a mooring post. When one of these four boxes was baited with food, the gorilla attained an accurate response after an interval of three hours without maintenance of orientation. From the control experiments that were carried out, it was ascertained that odors of the food, peculiarities in the appearance of the correct box aside from the color and location, and cues derived from the experimenter did not act as a basis for the gorilla's choice. Yerkes said that the gorilla did not depend upon secondary cues for a correct response; instead the food-box situation, as originally experienced persisted in some manner until the moment of response. The author did not attempt to determine the temporal span of memory accurately or to establish an extreme limit. With practice, the gorilla would probably have made adaptive responses after much longer than three hours, as obtained at this time.

In their experiments with the chimpanzees, Yerkes and Yerkes (25) placed food in one of four boxes similar to those used with the gorilla and these chimpanzees were able to make successful responses to position after 48 hours. The situation in which color was the differentiating factor was very difficult for them, although successful responses were made in delays up to 30 minutes. As with the gorilla, all the experiments conducted to see whether or not success was furthered by secondary cues such as odor of the food, position at release or the behavior of the experimenter yielded negative results.

The experience of eating the food was measurably more effective in determining a subsequent delayed reaction than was the experience of seeing the food deposited in a certain place. Fifty-eight per cent of the incorrect choices were the boxes in which the food had been obtained in the previous trial. Recognizing this tendency to perseverational response, Yerkes and Yerkes (25) plan to formulate a method for determining the relative mnemonic value of seeing a box baited and the experience of obtaining food from a given box, so that the trials can be properly spaced and thus avoid the conflict between the two factors.

A somewhat different method was used by Yerkes (24) with the gorilla. In this experiment, a turntable mechanism carried an

array of closed food receptacles or cans which differed in color, size, surface pattern, or all of them. The gorilla observed a supply of food placed in one of the cans while it was in a standardized position in front of the cage. Thereupon, the experimenter rotated the table from 90 to 270 degrees, and after interposing a predetermined period of delay, during which the gorilla could busy herself as she chose in the cage, permitted her to come to the grill, and by reaching through endeavor to reinstate the can containing the food, and obtain the reward by appropriately rotating the table. Positive results were obtained after delays of 10 minutes although an attempt was not made to determine the temporal limit for this variety of adaptation.

Tinklepaugh (17) in his investigation, although utilizing the delayed reaction technique, was more interested in discovering the representative factors which enabled the monkeys to respond correctly in the various experimental situations than in establishing maximum periods of delay. The experimenter placed some food under one of two cups, placed somewhat differently with regard to the subject in the four set-ups employed. A board was placed in front of the cups so as to prevent fixation during the delay interval. The monkeys were found to respond accurately to an absent stimulus after a delay of from 15 to 20 hours without bodily orientation. In order to analyze the processes involved in the delayed reaction, qualitative tests were developed in which lettuce was substituted, unseen by the monkey, for the banana. There were typical differences in the behavior of a monkey when he found the lettuce he had seen placed under the cup, and when he found the lettuce under the cup where he had seen the banana placed. Tinklepaugh believes that the nature of the subject's behavior when either the food or the container is secretly substituted is a criterion of the basis upon which he responded. In the actual choice of the container, however, the monkeys responded only to their relative positions, and the behavior when the substitution method was used merely demonstrated the fact that both the container and the reward were functional parts of the stimulus.

Nellmann and Trendelenburg (15) used a wooden box with a

hinged cover for testing memory in the monkey. Great care was taken so that the side that was hinged could not be distinguished on the basis of external appearance. If the food was placed in the box and the box turned 180 or 360 degrees in the horizontal plane, the monkey could react correctly after a very short interval, but failed to remember the side of approach if half a minute was introduced after the turning of the box. These same investigators used another method which is also applicable to the testing of the delayed response, although they did not utilize it for this purpose. A cherry was placed under one of two flower pots in front of the cage. The monkey could turn up the correct pot if they were turned 180 degrees so as to reverse right and left, or if the pots were each turned 360 degrees and thus returned to their original position only placed a little closer to the cage. The monkey was not diverted by the change, and continued with further experimentation making correct immediate choices.

Some less formal tests have been devised for use with animals, approximating natural conditions and therefore more comprehensible to the subjects. After Buytendijk (4) had thrown four pieces of apple successively in different directions, his monkey went to each one in turn, picked it up and ate it. After eating the third piece he paused a short time, and then went for a piece which had fallen underneath a board.

In Cowan's experiment (5), the cat received food in an adjoining room when the experimenter appeared at one door of the room, and did not obtain food when she appeared at another door on the same side of the room. After the problem had been mastered, delays were introduced, and the cat could respond correctly in a majority of the trials after a delay of 30 seconds without constant orientation.

Adams (1) modified Cowan's method somewhat by placing food in one of four boxes which could be entered by means of a door that was easily pushed open by a cat. The cat was taken out of the room, and after a predetermined interval of delay returned to the experimental room. During the interval all of the boxes were handled and filled with food, and the experimenter left the

room before the cat was released, so that no cues could be received from extraneous sources. With one of the two cats used, accurate responses were made after delays of 16 hours or more. The younger of the two cats was easily distracted, and could not respond accurately above 15 minutes after the food had been placed in the box. The long delays obtained by Adams appeared to be due to the ease with which the problem was learned and comprehended. Adams points out the marked conflict between the memory of seeing the food placed in the box, and the memory of having eaten the food in another box in the previous trial. To correct for this he believes that the interval between the trials should be about three times as long as the length of the succeeding delay period.

The buried food experiment was devised by Köhler and has been used with several types of subjects. Köhler (11, 12, 13) reports that apes are capable of delayed reactions, which according to his explanation, strongly suggest the use of memory ideas. Pears or tomatoes were buried in the sand just outside the cage and were so covered up as to give no visual or olfactory cues. The apes, having watched the burying of the fruit in the sand outside the cage, on being released after $16\frac{1}{2}$ hours, ran immediately to the burying place and dug out the fruit.

Yerkes (23) gave four trials in the buried food problem to the gorilla as a rough measurement of her memory span. He states that memory for locations in which food has been concealed persists for at least two days in the gorilla. Slight errors were made, however, in the estimation of distances. Upon returning after a week, she exhibited definite memory of her previous experiences in these locations. Positive results were obtained on the chimpanzees used by Yerkes and Yerkes (25) in the buried food experiment after delays of two days, with some indications of memory after four days. Evidences of memory for persons and situations have been observed after ten month intervals in both the gorilla (23) and the chimpanzee (25).

Kohts (14) has ingeniously devised a very different type of test for measuring delayed reactions. The chimpanzee was shown an object and required to select from a number of objects placed on

the table before it, an object identical in one or more respects with the sample shown by the experimenter. This experimental situation of choice from a sample offers many risks of error, but Kohts was well aware of these and controlled and checked her observations accordingly. By using this method the stimuli could be varied in place of presentation, relative position, form, time of exposure, number and arrangement. When a colored plate was shown for two seconds, the chimpanzee could make a correct choice from a number of different ones if the delay did not exceed 15 seconds.

Experiments with children. The delayed response has been more adequately and extensively studied in animals than in

TABLE 2

The length of delay secured with various children

SUBJECTS	DELAY	ALTERNATIVES	EXPERIMENTER	TRIALS ON DELAY
8 year girl	28 minutes	3 lights	Hunter (7)	38
6 year girl	35 minutes	3 lights	Hunter (7)	15
6 year boy	35 minutes	3 lights	Hunter (7)	47
6 year boy	25 minutes	3 lights	Hunter (7)	41
$2\frac{1}{2}$ year girl	50 seconds	3 lights	Hunter (7)	507
1 year girl	10 seconds	3 boxes	Hunter (9)	264
2, 5 year boys	1 minute	2 bowls	Tinklepaugh (17)	
$1\frac{1}{2}$ year girl	$8\frac{1}{2}$ minutes	3 bowls	Rugh (16)	28

children. The difficulty of securing young children and of developing a satisfactory method of investigation has seriously retarded the study of their mnemonic processes. Since there are so few experiments reported in the literature, each case will be included in table 2 summarizing the results of the various studies. In this table are given the age and sex of the subjects, the length of the delay obtained, the alternatives employed, the experimenter and the number of trials given on delay.

For testing the delayed responses of children Hunter (7) used a modified form of his apparatus for the animals. One of three lights was turned on over the button that rang the buzzer, and the child's problem was to find this button at the first trial, when the light was on (in the learning trials), and then (in the delayed

reactions) after the light had been turned off for a certain interval of time. Four of the five children used in this experiment learned the association between the noisy button and the light in six trials. The delays were increased continuously until an error was made, then either decreased, or continued on this level until there was a reasonable certainty that the maximum delay had been obtained. The delays attained ranged from 50 seconds for a girl two and one-half years of age to 35 minutes for a six year old girl. An eight year old girl who could press the correct button after a delay of 28 minutes, could remember the button that she had pressed last the day before. This brings out very strikingly, the effect of making an overt response in increasing the child's retention of a particular situation. It also suggests the possibility that under slightly different circumstances, children of the ages tested would be able to remember for much longer periods of time than is indicated here.

The measurement of the delayed response in children is further complicated by the varying effects of candy and praise as motivation in the response for individual children, of the diversions offered during the interval of delay, and the conversations occurring among the children between the trials. Hunter (9) eliminated the difficulties involved in this experiment, when he formulated a direct method not necessitating any training or accustoming on the part of the subject.

Hunter (9) tested his own child at 13 months by using three boxes with hinged covers in which desired toys could be placed. The child was seated in front of the boxes, all of which were within easy reach, and her attention was directed to the placing of the toy. After a predetermined interval, during which time she was prevented from getting the toy, she was permitted to respond. She opened the correct box first in 72 per cent of the trials after delays varying from 8 to 12 seconds. Hunter noticed a tendency to open that box first in which the last toy had been found. Bodily orientation played a more significant part in this child's responses than in the responses of those children used in the three-light buzzer situation, where bodily orientation played no discernible rôle in the reactions. Hunter (9) interprets her

correct responses as a result of certain cues which were associated with certain differential responses and were selectively re-aroused when she was again confronted with the three boxes.

In order to compare children's behavior with that of monkeys when substitutions were made, Tinklepaugh (17) placed pieces of candy under one of two plates, and in the absence of the child substituted a different kind of candy. After one minute delays, both of the boys tested went immediately to the correct plate, and on finding a different type of candy than the one placed there, they evidenced similar surprise and behavior as that shown by the monkeys under similar circumstances. In a comparable situation, when Rugh (16) placed an object under one of three pans in front of a child one and one-half years old, she was able to react correctly after an $8\frac{1}{2}$ minute delay.

The duration of an impression after which one recollects a past experience has been demonstrated in Wislitzky's, "Experimente über Gedachtnis und Erwartung in der fruhen Kindheit," of which a preliminary report is given in Bühler's book (3). If an object is hidden, the child is then diverted for a period of time, and later permitted to seek it if he remembers the disappeared object spontaneously, the period of delay after which a correct response can be made increases from 5 minutes at one year to 20 minutes at two years, and 30 minutes at three years. There is no further increase in the length of the delay, but the number of objects that can be remembered increases from one at one year to six at six years.

Several authors have used geometric figures for testing immediate memory, and although they have not applied these to the measurement of delayed responses, they suggest their use for this purpose. In the tests developed by Fischler and Ullert (6) for the study of immediate memory, two of the tests are suited to preschool children, the presentation of pictures and the geometric designs. Thirty pictures, all familiar to the children were presented in succession, and after ten seconds they were required to tell something about each of the pictures seen. In another test nine geometric figures were exposed on a board for ten seconds. After 30 seconds, the child was asked to choose the nine blocks

from 25 that were placed before him. This test was first developed by Bernstein (2) for feebleminded children. The figures were chosen because they had no appropriate names, no associative value, and so that at least one figure could easily be confused with each of the ones seen. The performance in this test, as opposed to one in which forms having some previously existing association were used, is largely dependent upon the ability to perceive minute differences. The development of the concept of like and different in the perception of geometric forms is an important factor in the child's ability to make an accurate and discriminating response. A clearly defined perception is of even greater importance in a delayed response than in an immediate one.

The foregoing review of the literature on delayed reactions indicates very plainly the need of further studies of both animals and children. In formulating the various methods for studying the delayed responses of children, an effort has been made to utilize the advantageous elements in the previous investigations and to obviate as far as possible the undesirable features of the methods that have been used.

II. EXPERIMENTAL RESULTS

Purpose of the experiments. Four methods for measuring delayed reactions in young children were formulated in order to answer certain questions centering around the general problem. Up to the present time, no satisfactory maximum periods of delay after which correct responses can be made have been determined for a sufficient number of children to render the results statistically reliable. The majority of the previous experiments have been carried on with single children over comparatively short periods of time.

Finding the maximal period of delay for each child in the various experimental situations has been an important, but not the only purpose of this investigation; in fact in many cases this could not be obtained satisfactorily. The behavior of the children when the stimulus was given, during the delay period, and when they were confronted with the situation for the response were

recorded in detail for each trial. The vocal responses as well as the overt bodily behavior offer some cues as to the manner in which the child actually remembered how to respond correctly after the delay, and as to the individual differences in the length of the maximum delay obtained. The children's responses after several trials also gave interesting data as to the relative menmonic values of the stimulus given and the previous responses made by the child.

Besides their value for studying the simple delayed reaction, the tests have been chosen because they offer further possibilities for experimentation. When maximum periods of delay have been established for individual children, a basis will be provided for determining the consequences of modifications in the procedure upon the length of the delay attained and their behavior. Formerly, no adequate technique had been devised that gave maximum periods of delay sufficiently short to permit the measurement of the effects of varying the stimuli. Unless the maximum delay is comparatively short, due to the rapid mental growth of children at this age, and to the necessity of long intervals between the trials to avoid the perseverative effects of previous responses, the child becomes a different individual before enough trials can be obtained to secure any definite results. In an attempt to devise a method which would satisfy the above requirement, several tests were adopted and tried out, the procedures and results of which will be described in this chapter. The situations satisfy the criteria for the measure of a delayed response as formulated by the previous investigators, in that they are adapted to the subject, require no trials for learning the manner of response demanded, provide a means for presenting one of several stimuli which are equally effective, and present no differential cues to the subject during the period of delay. The experiment necessitated behavior similar to that in numerous other experiences of the nursery schools in which the subjects were enrolled.

General procedure. In each of the experiments, the period of delay after the first trial was determined for each child by his success after various intervals that were interposed after the

presentation of the stimulus. For the first trial, a period of approximately equal duration was introduced for all of the children. The intervals that were planned, however, could not always be carried out; due to absences and to changes in the nursery school program. The measurement of the maximum length of the delay is necessarily largely a trial and error process, since it is impossible to determine exactly the time when the child distinctly remembers the correct response, and when he forgets it. In fact, it is highly probable that there is a "zone of forgetting" where the remembered stimulus is gradually losing its potentiality for evoking a response. The trials were not as widely separated as could be desired, but since the experiments were in a formative stage, it was believed that the increased number of trials on individual children would more than compensate for the lessened reliability caused by the perseverative tendency in successive responses.

Observations. A cumulative record card was kept for each of the children for each experiment in which he participated, on which was recorded the stimulus given, the date, hour, behavior, and verbatim responses, for both the presentation of the stimulus and the response for each trial. All of the children in these experiments were given numbers according to their date of birth, and will be referred to by these in the subsequent discussion. The maximum delay, in case one was determined, the child's chronological and mental age at the time when the stimulus for this maximal delay trial was given, were tabulated for each experiment participated in by the child.

The maximum delay, so called, is not the greatest possible delay for that child in a particular experiment, but that delay which has been determined on the basis of many trials, and which is the greatest possible delay that could be obtained under the described conditions. In determining this maximum delay, each child's records were carefully analyzed in order to select the longest delay obtained with an unquestionably correct response. The child's conversation, his speed and behavior in reacting, as well as his responses on other trials were utilized in the determination. This value is affected to a certain extent by the length of

the delays used, as well as the judgment of the correct response, or one which appears to be questionable or due to chance. Whenever there were sufficient data, however, to permit an estimation of this maximum delay, it was recorded, since this furnished valuable results as to the nature of the child's reactions in the various experiments, and material for comparative purposes.

In order to provide additional material for this study, moving pictures were taken of several children reacting in the four experiments. From these, a number of prints were made which will be discussed in connection with case studies of the children in the various experiments.

Subjects. Sixty preschool children acted as subjects in this investigation. Since the length of the delays given was determined largely by the experimenter's evaluation of the child's performance, it was decided that an intensive study permitting of many trials for individual children would be more valuable than securing a few scattered trials on a larger number of children.

Forty-nine children were in the Child Institute at the Johns Hopkins University. Nine of these children were tested at various intervals for two years, the others either during 1928–1929, or 1929–1930. This group included children whose chronological age range at the time when the first delayed response trial was given was from two to five and one-half years.

Eleven of the children were obtained from the Arbutus Methodist Nursery School. These children varied in age from three and one-half to five and one-half years. They had never been subjects for any experiments or formal tests up to the time when they were used in this investigation.

The mental ages, as derived from the Stanford-Revision of the Binet-Simon tests were available on 35 of the children from the Child Institute. Eight of the younger children and those who were only temporarily enrolled in the Nursery School had not been given this test. Ten of the 11 children in the Arbutus Nursery School were tested by the experimenter. Every possible effort was made to obtain mental ages on all of the children, so that the omissions may be considered unavoidable.

A brief summary is presented in table 3 of the children included

and the number of trials given on delay in the four experiments. The number of trials that were not completed, due to absence of the subjects, is given in the column at the extreme right.

Due to the impossibility of obtaining a large number of preschool children, many of those employed in this study were given more than one of the tests. The extent of the overlapping in the tests may be gathered from the following data: 17 children were given all four experiments, 5 were given three, 17 were given two, and 21 children were given only one of the experiments. In several cases, two of the experiments were carried out on the same child during the same period of time, thus introducing some interferences, but the results indicated that this concurrent double

TABLE 3

A summary of the experiments given

TYPE OF EXPERIMENT—DELAYED RESPONSES TO:	NUMBER OF ALTERNATIVES	NUMBER OF CHILDREN	NUMBER OF TRIALS INCLUDED	NUMBER OF INCOMPLETE TRIALS
I. Position of a concealed object	3	46	280	5
II. Exposure of familiar forms	6	27	120	3
III. Exposure of geometric forms	6	37	242	8
IV. Exposure of unfamiliar forms	6	28	121	2
Totals			763	18

series did not detract from the value of the data obtained. As far as possible, the trials on the children used in more than one experiment were distributed so as to minimize the conflicting effects. The actual time spent in the experimental room was approximately one minute for giving the stimulus and for the response, although in some cases the latter was a trifle longer when there was a marked hesitancy on the part of the subject in making a choice.

Throughout this study, the investigator encountered no difficulties in securing the children's cooperation. Two of the younger children were a little hesitant the first time that they were asked to "come and play the game," but this reluctance was soon replaced by a willingness and even eagerness to come with the experimenter. Comments such as "Take me," "Can I

come next time?" or "When will it be my turn?" were frequently made. Several of the children came to the experimental room without being asked, hoping that they would be given a trial. This behavior was manifested, equally, with regard to each of the four experiments.

I. Delayed responses to the position of a concealed object

Experimental procedure. In the first experiment an animal cookie was hidden, in the presence of the child, under one of three plates, and after a definite predetermined interval the child was again confronted with the situation and asked to find the object. The apparatus consisted of three china soup plates placed on a table 28 by 45 inches at a distance of 6 feet from the subject, who was seated on a small chair when he was not reacting. Animal cookies were chosen as the stimuli, to be used also as rewards, because they were not harmful as food, the children liked them, and because they could be readily eaten and thus disposed of without offering any accessory stimulation to the children beyond the experimental room.

The child was asked to come with the experimenter into the experimental room where he was told to sit on the chair facing the table on which the soup plates were placed. The experimenter took the animal cookie in her right hand, and showing it to the child said, "Do you see this little animal cookie? (Paused for the child's assent.) Now I am going to hide the animal cookie under *this* plate. (Lifted a plate with the left hand, and placed the cookie under it with the right hand, standing always to the right of the plates so that they were within full view of the child, stepped back from the table and continued.) If you can find the animal cookie when you come back here, you may have it to eat. Now you may go and play."

The animal cookies were placed under the plates in a definite sequence but in an irregular order. Each plate was used an equal number of times in order to prevent habitual responses to one position, but the same plate was never used in two consecutive trials.

After a predetermined period of time, the child was again

brought into the room. As soon as the child was seated, the experimenter took a position a little to the right of the subject's chair and asked the child, "Can you find the animal cookie?" No other directions were given, but these were occasionally repeated in case the child did not hear or comprehend the directions the first time. When the child got up to respond, the experimenter immediately passed out of the child's field of vision and could only be seen by him if he turned his head around while going to the plates. Unless the child had received some cue from the experimenter while the directions were being given, there was no possibility of him receiving any without that the turning of the child's head gave evidence of his indecision in the choice of the correct plate. If the correct response was made, the child obtained the animal cookie, and after having eaten it, went out to play. If the child turned up the wrong plate, this was said to the child, "You didn't find the animal cookie today did you? (Pause.) I guess that you will have to come back some other time to see if you can find it." There appeared to be no disinclination to react in this experiment in spite of continued failure to obtain the reward in successive trials.

The procedure in this situation needs some justification, since it departs slightly from that reported by Hunter (7 and 8), Tinklepaugh (17), and Rugh (16). A certain stimulus may have varying effects upon the length of the delay possible, due to the nature of the accompanying circumstances. In one case, the so called "release" for the response may be one which is associated with the response by practice, such as releasing the bar in Hunter's experiment (7) with the children. In a second case, the procedure in the response to the stimulus may be such as to definitely suggest the type of behavior required. There is less difference between the two methods described than would appear at first. When the child is trained to respond to a given release, this release has, obviously, just as much associative value in a given situation as the directions, "Can you find the animal cookie?" In either case, the child is still required to discriminate between the three plates presented, and to decide which one to lift up in order to obtain the reward. The only real difference

between the bodily release and the verbal command is the advantageous elimination of a learning series in the latter method.

In spite of the fact that an attempt was made to make this experiment as natural as possible, the objection might justly be brought against it, that the child rarely has to look for food under inverted plates, or to discriminate between three objects identical except for differences in position. Nevertheless, the situation was easily comprehended by the children and proved valuable in studying certain aspects of the delayed response. Its practicability for determining a child's maximum period of delay in a relatively simple situation was also demonstrated.

Experimental results. Children's behavior and verbal responses. A child's reaction to a new situation is very suggestive of his general behavior. His comments, ability to adapt to the new demands made upon him, and his interest in the first trial correspond very closely to that observed in later trials. Significant behavior observed, bearing upon the conditions of the experiment as a whole will be discussed here, while that pertaining primarily to interesting individual children will be given in a study of special cases.

The children were eager to find out about the new "game" they were asked to play. The reactions to the hiding of the animal cookie were varied in many respects. Several children pointed to the plate where the object was hidden, others reached for the cookie, and a few attempted to go to the plate immediately. In each case, as soon as the procedure for the stimulus presentation was completed, the child was sent back to his play group. One child commented, "That's a pretty trick, isn't it?" Very soon after the object had been hidden, several children asked if they could not come with the experimenter again. One child came from second to first floor without receiving permission, and peeked in the door to the experimental room, with a very questioning expression on his face. When he was told that he could come back tomorrow, he immediately returned to his group.

The responses in the first delayed reaction trial ranged from complete compliance with the directions and immediate success, to absolute failure due to non-comprehension of the directions

or refusal to respond. Many children manifested uncertainty in choosing the plate where they looked for the reward. In such cases they would ask, "Where is it?", or "Is it in this plate?". Where this indecision was noted, the response was considered a failure or a questionable success. A number of the younger children hesitated in lifting the plate, usually shoving it around, looking helplessly at the experimenter at frequent intervals. These children were urged to lift the plate they were responding to, so as to obviate the occurrence of this type of response in later trials. The one child who did not understand the directions at all in the first trial, had learned English very recently, and it was necessary to give him several trials in order to teach him what was required in the response.

Many children as they became increasingly familiar with the experiment, began to leave the room as soon as the cookie was hidden, before the directions were completed. When responding, they began to walk towards the plates as soon as they heard, "Can you find," instead of waiting for "the animal cookie," which indicates that the question merely acts as a "release" at the time for the response. In most cases the child was not permitted to lift up more than one plate, whether the response was correct or not. When this was allowed, it was in order to study the child's behavior, and in two instances to avoid a potential emotional upset which would, perhaps, have conditioned the child negatively to the experimenter. A majority of the children took this prohibition as a matter of course, and did not attempt to lift up any other plate if they did not obtain any reward under the first one.

As well as indicating uncertainty concerning the plate to be responded to, most of the children at one time or another throughout the experiment, expressed a curiosity concerning the whereabouts of other animal cookies. The most frequent expressions were, "Are there any under there?", indicating the other two plates not responded to, or "Where do you get the cookies?", "Is everybody going to get one?", or "I have animal cookies at home." A few of the children asked if another child, giving his name, had received a cookie, or if they were afraid that some other child would take it before they returned to the room they would

say, "Don't let—get it, will you?", or "I bet somebody takes it," or "Now don't you give it to anyone else."

When a child did not find the reward, he usually assumed one of two attitudes, either he admitted forgetting, or he excused himself on the basis that the experimenter or some child had taken the reward in his absence. After an absence of 40 days, child 10, when asked to find the animal cookie replied, "Staying at home and sleeping made me forget." Another child volunteered, "I always forget to go in here and get it." Other children simply said "I forgot." Two of the children asserted that the experimenter had fooled them, the one angrily, and the other behaving very complaisantly as if it were a part of the game. One child, when he did not find the reward asked, "Who ate them all up." The spontaneous remarks made by the child when the cookie was hidden and when he did or did not find it, were the only cues that could be obtained as to the nature of the mnemonic processes involved. When the final trial had been completed on each child, if he had found the reward, he was asked, "How did you find it?" No amount of questioning would elicit any answers other than, "I just remembered," "I don't know," "I saw you put it there last time I was here," or "I knew it was there."

All of the children were pleased with the game and the reward. Some of the children wished to take the animal cookie to show the other children, but they were requested to eat it in the experimental room so as not to disturb the other children. One child did not eat the cookie saying, "I am going to save the cookie, because my mother won't let me eat between meals." The reward part of the situation was the only one mentioned by any of the children in their play group. The nursery school teachers reported that in no instance throughout any of the experiments, did the children mention any of the conditions in either this situation or in any of the others except the fact that they had found or had not found the animal cookie. This was most gratifying, since all conversation and reenforcing of the stimuli given through repetition would seriously interfere with the validity of the delays obtained. The group apparently had no effect upon the reactions in the experiment except to accentuate the desire to participate as frequently as possible.

When the children became more accustomed to the situation, their attention was not centered solely upon the process of seeing the cookie hidden and finding it after a period of delay. Several children requested, "Let me hide it," or "Put it under the middle plate this time." One child asked, "Why do you put it under there?" Comments were frequently made concerning extraneous matters such as the child's new clothes, his activities, objects about the room, and his play at home.

Quantitative results. Interesting and valuable as this description of the children's behavior and verbal responses in this experiment is, a quantitative analysis of the results obtained is also necessary. The data do not lend themselves very well to statistical treatment, both because of the limited number of cases, and because the determination of the delays is not entirely objective. The statistical analysis of the data is not final in any sense, but merely suggestive and indicative of results that would probably be obtained by further study of additional children.

TABLE 4

The frequencies of the stimuli and the responses in percentages for the various positions of the plates

POSITION OF STIMULUS	TOTAL NUMBER OF TRIALS	RESPONSES IN PER CENT OF TOTAL NUMBER			
		1	2	3	None
1	93	61.5	26.8	8.5	3.2
2	89	17.9	59.5	22.6	
3	98	18.4	23.5	56.1	2.0
Totals.....	280	32.5	36.1	29.5	1.8

The plates under which the object was hidden were numbered according to position from left to right, one, two, three, and will be referred to in this manner. The frequencies of the stimuli and the responses in percentages for the various positions of the plates are given in table 4.

The total number of times that a cookie was placed under plate one, was 93 times. Of the responses in these trials, 61.5 per cent were correct; of the incorrect ones, 26.8 per cent were to plate two, 8.5 per cent to plate three, and 3.2 per cent were not re-

sponded to at all. Each plate was used approximately the same number of times as a stimulus, but in spite of this fact, there was a marked preference for the middle plate. A larger proportion of the incorrect responses were made to plate two, then to either plate one or three. This may be due primarily to the fact that since the table was straight, the side plates were a little further away from the subject when he was seated for the response, than was the middle plate. Further, when the child was uncertain as to the plate where the animal cookie was, he would walk to the table, fluctuate in choosing between all three plates, remain standing near the middle one, and finally lift this one up in order to obtain the reward if it was there. No cues were derived from the children affording any explanation of the few incorrect responses

TABLE 5

An analysis of the incorrect responses made in Experiment I

INFLUENCING FACTORS IN THE 115 INCORRECT RESPONSES	PER CENT
Response made in preceding trial	44.4
Habit response (made in several preceding trials)	17.4
Hidden in previous trial	13.9
Incorrect response in first trial to middle plate	6.9
No basis for choice	13.9
No response	3.5

made to plate three, when the cookie had been hidden under plate one. One would expect more confusion between the end plates than actually occurred. Several of the older children did not remember where the cookie was, and did not guess at the place where this might be obtained, hence no response was recorded for this trial.

The nature of the errors made in this experiment manifest, very strikingly the marked perseverative effect of the previous correct response. Of the total number of incorrect responses made (115), the proportions given in table 5 constitute some interesting results.

Combining responses due to habit, and to only one previous correct response to that plate, it will be seen that 61.8 per cent

of all the incorrect responses may be considered as perseverative. It is only reasonable to expect that when a child has seen an object which he desires placed under a plate, and that subsequently it has been obtained there, that he should go to this plate again when making the next response, in spite of a different intervening stimulus, providing the interval between trials is not sufficiently long. In cases where the child made a correct response after, for instance, two days, and made an incorrect perseverative response after two days in the succeeding trial, the former delay was considered as a definite indication of memory for the stimulus, whereas, if the latter failure had not been perseverative, the correct response after a two day interval in the first case was considered as questionable, providing the child's behavior in the two cases did not permit of accurate evaluation.

It would have been profitable to study the length of delay possible for obtaining a perseverative response, providing this had been planned in setting up the experiment. The situation would enable a comparison of the length of time which a child could remember when he had been stimulated once or twice, since responding in a given trial is equivalent to strengthening the previous stimulus. With the data obtained in this experiment, the above analysis would be of little value, since the intervals between the trials were much less objectively determined than the lengths of the various delays used. Furthermore, when there are only three alternatives, if the response is incorrect, the chances are half and half that the response will be perseverative, because no plate was ever used twice in succession as a stimulus for one child. Individual children differed markedly in the frequency of incorrect perseverative responses. It appears that for them, the receiving of the reward had greater menmonic value in comparison with seeing the cookie placed under the plate, than it had for other children. Individuals who continue to respond incorrectly to the same plate three times in succession differ greatly from those who never make an incorrect perseverative response despite a comparable trial series. A greater number of incorrect perseverative responses were noted after the first trial than after any of the succeeding ones. This was undoubt-

edly due to the greater attention and interest manifested in the new situation which enabled the child to remember the stimulus longer than when, in the later trials, he had had several different stimuli presented to him.

In order to determine any relationship existing between the length of the interval between the trials, that is from the response in one trial to the stimulus for the next trial, to the length of the delay obtained in the succeeding trial, these data were tabulated according to three characteristics: the length of the delay in each succeeding trial, the success or failure of the response, and the ratio of the interval between trials to the length of the delay in

TABLE 6

The proportion of correct and incorrect responses for various ratios of the interval between trials to the length of the succeeding delay in Experiment I

INTERVAL ÷ LENGTH OF SUCCEEDING DELAY	NUMBER OF RESPONSES INCLUDED	PER CENT CORRECT	PER CENT INCORRECT	PER CENT OF WHOLE GROUP
0.0–0.4	55	45.4	54.6	23.5
0.5–0.9	28	60.7	39.3	11.9
1.0–2.9	58	43.1	56.9	24.9
3.0–9.9	36	66.7	33.3	15.3
10.0–19.9	22	72.7	27.3	9.4
20 and over	35	71.4	28.6	15.0
Totals........	234	53.8	46.2	100.0
First trial....	46			

each succeeding trial. This ratio was obtained by dividing the length of the interval between every two trials by the length of the succeeding delay. The importance of determining the interval between trials for securing reliable maximum delays may be gathered from table 6 giving the proportion of correct and incorrect responses for various ratios of the intervals between trials to the length of the succeeding delays.

Since there are 46 children included in this first experiment, there are 234 trials on delay included in this table, because the first trial was, of course, not preceded by an interval to form a ratio. For the shorter delays, the ratio was greater than for the

longer ones, since obtaining several trials with long delays necessitated the utilization of the time in the delay period rather than in the interval between trials.

It may be noted from table 6, that although the increase is not uniform, the proportion of correct responses increases from 45.4 per cent when the ratio is less than 0.5 to 71.4 per cent when this ratio is over 20, that is, when the interval between the trials is at least 20 times as great as the length of the delay in the succeeding trial. The fact that these ratios are more prevalent with the shorter delays, which also have a greater proportion of correct responses, makes it difficult to allocate the causative factor. Undoubtedly both play an important part in the results obtained, but the predominance of incorrect perseverative responses in the errors made suggests that well spaced trials will give the most valid results, at least in so far as obtaining satisfactory maximum delays are concerned. Approximately three-fifths of the trials were given after intervals of less than three times the length of the delay on the following trial. Until satisfactory techniques have been evolved, there are so many other sources of error in measuring the delayed reaction, that one is justified somewhat in neglecting to adhere strictly to any definite ratio. But it is certain, that unless the trials are spaced at least partially in accordance with the length of the delays used, the results will be so conflicting as to prove of slight value, even in formulating a method of study.

The data were also combined with reference to the success of the responses in relation to the length of the delays used.

The proportion of correct and incorrect responses as given in table 7 indicates a decreasing percentage of incorrect responses after longer periods of delay. This means that a majority of the children could respond successfully to an absent stimulus after a short intervening period of time, but that as these intervals increased, more of the children failed to respond correctly, notwithstanding the fact that the delays were based primarily upon each child's performance in preceding trials. All of the trials given are included in this table, so that the totals differ slightly from

hose in table 6 where the 46 first trials are not included. The percentage of correct responses decreases from 64.8 after delays of from one to three days, to 28.6 after delays of over 30 days.

Maximum delays were obtained on 42 children in this experiment, but these results will be included in a comparison of the delays obtained in the four experiments, together with the relationships existing between these delays and certain other factors.

Case studies. In a statistical analysis of data such as has been given in the preceding pages, interesting features of the individual records are hidden. Some cases have been selected which demonstrate the type of behavior manifested, both when the stimulus

TABLE 7

The proportion of correct and incorrect responses after various periods of delay in Experiment I

LENGTH OF DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT
days			
1–3	142	64.8	35.2
4–9	71	55.0	45.0
10–14	25	52.0	48.0
15–20	9	44.4	55.6
21–29	26	46.2	53.8
30 and over	7	28.6	71.4
Totals............	280	57.9	42.1

is presented and when the delayed response is made, and which throw some light on the effects of various uncontrolled factors in the experiment upon the length of the maximum delay obtained. The length of time necessary for both the stimulus presentation and the response was longer than in any of the other experiments, and hence the records provided a greater wealth of material for individual analysis. Cases have been chosen which illustrate the ability to make correct responses after long periods of delay, the perseverative effect of a correct response, the effect of excitability, high emotional tension, and variations in the stimulus upon the length of the delay obtained.

Child 37

This child responded correctly after the longest delays of any of the children tested; in none of the trials was an incorrect response or even a questionable correct one made. She was given two trials in 1929; having made a correct response on the first trial after one hour, she made an immediate correct response on the second trial after an absence of 64 days. She went directly to the plate where the cookie had been hidden the time before, and when asked, "Are there any cookies under the other plates?" she answered, "No." Since this delay was three times as great as that obtained for any other child, it was not counted as a maximum delay. In 1930, she responded correctly after a delay of 34 days, which was also longer than any delay obtained for any of the other children. Her chronological age at this time was 50 months, and her mental age 65 months. At the time the cookie was hidden for the last trial, she gave some evidence of the method she used in remembering, and gave adequate justification for assuming the delayed response after 34 days to be a result of correct memory. She pointed to each of the plates, saying as she did so, "I look at them and say, one, two, and than I look under three (stimulus in this case) and get the animal cookie." By reenforcing the stimulus in this way, she was enabled to make a correct response after a much longer period of time than she would have if she had not used these memory devices. Her responses in the other experiments were about the average for her age.

At the age of 38 months, this child came up to the experimenter and said, "See my new watch." About 20 minutes later she said, "See my new watch. Oh, I showed you before didn't I?" About 15 minutes later she said, "I showed you my watch before didn't I?" This incident is illustrative of her general behavior.

Child 17

No child expressed such great satisfaction with his ability to respond accurately to this situation as did child 17. When the cookie was hidden the first time he said, "I saw where. I know right where you put him, because you put him right under that plate" indicating the plate. After responding correctly in the first trial he said spontaneously, "I can find it because I saw you. There aren't any under there, are there? Why didn't you put it under there?" He surveyed the reward disparagingly, "This is too little for me to take home." His maximum delay was 17 days when he was 53 months old with a mental age of 70 months. His superior attitude in this experiment was consistent with

his behavior in the nursery school, where he always maintained that all the toys belonging to the school were mere nothing as compared with the marvelous things provided in his home for play.

Child 55

The marked perseverative effect of receiving an animal cookie under one plate upon subsequent responses is remarkably demonstrated in this child's record. He obtained the reward in the first trial under plate one, and continued in the next four trials to make incorrect responses to plate one, without the slightest hesitation. He then made a correct response to plate two after a delay of one day, and continued responding to this plate for the remaining six trials given him. With a child of this sort, it is absolutely necessary to keep the intervals be-

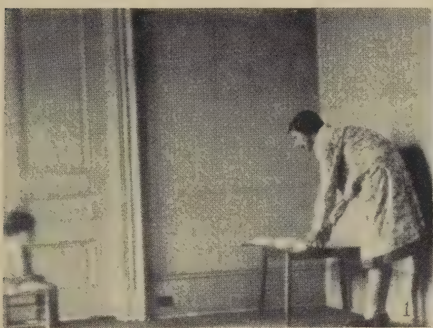

Fig. 1. Presentation of Stimulus Experiment I

Fig. 2. Response in Experiment I

tween the trials at least three times that of the length of the succeeding delay. For this child, the interval could profitably be increased to ten times. His maximum delay was one day when he was 32 months old.

This child is shown watching the hiding of the animal cookie, and lifting up the correct plate in figures 1 and 2 respectively.

Child 51

This child exhibited the greatest variety of interests in his conversation before, during, and after the trials in this experiment. His maximum delay was six days when he was 43 months old, and had a mental age of 56 months. When coming downstairs for the first trial he volunteered, "I smell chicken. I smell fish." When I showed him the

animal cookie he said, "Can I smell it?" After I had hidden the object, it was difficult to persuade him to leave the room. He insisted, "I want to see the animal cookie." When the experimenter suggested that he go finish his steamship, he returned to his play group immediately. Coming downstairs for the response on the first trial, he said, "Can I have the animal cookie?" After obtaining the reward he asked, "Are there any under there?" pointing to plate two, and later, "Haven't you got any more?" At each stimulus presentation he would invariably say, "I see," and when asked to find the animal cookie, "I could." He manifested great reluctance in leaving the experimental room, either coming back and peeking through the partly open door, or making elaborate plans for his return at a later time for finding the reward. His favorite expression when he saw the experimenter at any time was, "I have come back," suggesting that he would like to be of service.

After an absence of three months, on seeing the experimenter in the hall upon his return, he said, "Miss S.—, can I get the animal cookie?" The stimulus was given, and he wanted to look for the reward immediately, "Why can't I get it now?" He made a successful response after six days in this case. At all times he showed a great desire to obtain an animal cookie. It is impossible to say whether his interest in the "game" or his scattered attention had the greater influence upon his memory for the position of the plate containing the concealed object.

Child 27

Child 27 was a foreign-born child who had learned English very recently and did not understand it very well. When the stimulus was presented, his expression was always, "What is that?". He did not understand the purpose of the experiment, and failed to find the cookie after a two day delay on the first trial. He was then given a trial with a one minute delay, and his response at this time indicated the nature of his difficulty. He went over to the table and *looked* at the writing on the bottom of the plates, as if to find the object pictured there. He was urged to lift the plate, in order to teach him the method of response and he found the cookie. Upon returning to the playground, he jumped up and down hilariously, saying repeatedly, "I had a good time." On the third trial he wanted the cookie when he saw it, and asked "Why can't I have it now?" In all succeeding trials, however, he left the room as soon as the directions had been completed, having learned that an interval must elapse before he would be permitted to look for the cookie. In the response in this third trial he said, "It is under this plate," walk-

ing to the plate and obtaining the cookie there. According to his teacher he had been irritated all morning because he had not been permitted to react in the experiment, and the experimenter was greeted with, "You said I could come next time," in an accusing tone of voice. In the next trial when he did not find the reward, he could scarcely be made to leave the room, because he wanted to look under the other plates. When he asked, "When can I find it?" and was answered, "Some other time," he said, "I want to be by myself," perhaps because he thought that he could find the reward better then. He made an incorrect response in the following trial but was permitted to look under the other plates to find the cookie in order to avoid any emotional difficulties such as were threatened in the previous failure. A somewhat longer delay was then tried, and in the response situation he walked immediately to the correct plate, hesitated and said, "You find it. Sometimes I don't find it." He walked around the room, returned to the plates, started lifting up one, put it down, went to two, returned to one and found the cookie there. His maximum delay was three days, when he was 56 months old, and had a mental age of 56 months. His excitement both during the stimulation and when he was responding, undoubtedly prevented him from remembering the position of the concealed object for a long period of time.

Child 4

This child was perhaps the least stable emotionally of any of the children tested. The atmosphere in the home was unfortunately not very frank, and the child, herself, was quite adept at fabrication. She could not find the animal cookie if delays were introduced of longer duration than 30 hours. Her responses when she failed to find the reward were either, "I am never coming down again," "You told me a lie," or "You fooled me." At another time when she did not find the cookie she said, "You told me last time you would tell me where it is. You are telling me stories." There never seemed the remotest possibility to her, that she could have forgotten where it was, or that it was through any fault of hers that she failed to find the cookie. After an interval of one day, when coming downstairs she said, "Did you put it an easy place for me? I am going to get it today. Now you watch me." She found the reward and wanted to take it upstairs. In spite of the predominance of incorrect responses she was always certain that she would obtain the reward before her response had occurred. She attempted to attract attention in various ways, either by falling off her

chair, or making queer faces. Her continual excitability prevented her from concentrating on any one thing long enough to remember it for any but a very brief period of time. Her chronological age when the maximum delay of 30 hours was obtained was 61 months, and her mental age was 63 months.

Child 40

An interesting example of the effect of the variation of the stimulus upon the length of the delay possible is demonstrated by this boy. He apparently was much interested in the experiment, but in the first six trials he was not able to remember the position of the cookie longer than half an hour. His mother, at this time, told the experimenter that the child was very fond of elephants, and so elephant animal cookies were used. When the object was hidden the directions given were, "Do you see this elephant cookie? etc." He had no difficulty in remembering where the *elephant* had been hidden after a delay of one day. His chronological age at this time was 39 months, and his mental age was 47 months. The use of the elephants instead of any kind of animal cookie increased his desire for the reward and enabled him to remember its hiding place longer.

Summary. Forty-six children were given a total of 280 delayed response trials in this experiment, where memory for the position of a concealed object was tested. The maximum delays obtained ranged from 1 to 34 days. Approximately three-fifths of all of the stimuli given were responded to accurately after the delays given. A majority of the incorrect responses were made to position two, that is the middle plate. The most influential factor in making an incorrect response was having obtained the reward in a certain position in the previous trial. The responses after shorter delays were correct in a larger proportion of cases than after longer periods of delay. More of the delayed responses were correct if the interval between the response on one trial and the stimulus in the succeeding trial was at least three times as great as the delay in the succeeding trial. The records chosen for individual analysis indicate interesting features of the delayed responses which could not be treated statistically, but which do give valuable data as to the manner in which a correct delayed response is made, and as to variations in the maximum delays obtained by different children.

The length of the periods after which the position of a hidden object could be responded to correctly was so great, that it would have been impossible to study the effects of modifications in the procedure upon the length of the delay obtained, by the use of this test. In order to get a situation which would yield maximum delays of short duration, and to study the children's reactions to a somewhat different set-up, experiment two was devised, using familiar forms as stimuli.

II. Delayed responses to the exposures of familiar forms

Experimental procedure. The delays obtained in the first experiment were too long to permit of any measurable variations. For this reason, several supposedly more difficult tests were developed. In this situation the control of conditions was planned for a more difficult response, offering multiple choices. Previous to the actual delay trials it was necessary to test each child's familiarity with wooden blocks of various forms, and his ability to name them. Two of each of these forms were made and outlined in black: a dog, horse, cat, camel, automobile, elephant, boy, duck, goose, kiddie car, rabbit, pig, and chicken. The method was similar to the one used by Kohts (14) with the apes, although her primary interest was in the ape's ability to discriminate form and color.

In the preliminary experiment, the forms were placed on a table within easy reach of the child who sat facing the table. The apparatus and method of presentation is illustrated in figure 3. Each form was presented in turn with these directions, "Do you see this block? (Holding one up immediately in front of him.) Will you point to one on the table exactly like this one?" Provided the child responds correctly the experimenter asked, "What is it?". Whenever the child could name the block, but not point to the one like it or vice versa, the fact was recorded. The six blocks that were chosen, were accurately pointed to and named by all of the children who could respond satisfactorily to the absent stimulus in the delay trials. The four youngest children in the group tested, could not name more than one or two of the forms, and did not understand the matching process. They were

given several trials on delay, but their responses gave no evidence of memory for the previously presented stimulus. The records of their performances are included in the discussion because of the interest attached to their behavior in a situation too difficult for them. The previously planned training of those children who were not familiar with the forms, in order to insure comparable effects of the stimuli, was therefore unnecessary. The blocks chosen were a kiddie car, cat, boy, rabbit, pig, and automobile.

Fig. 3. Testing for Familiarity of Forms

Although all of the children could readily point out and name each of these forms correctly, there was no assurance that they had equal mnemonic value, in fact one is led to believe from the experimental results obtained in this test, that they differ greatly in this respect, due primarily to the variety of their associations for the different children.

A form was shown in an exposure box constructed for this purpose. The box was 25 by 25 inches, and the form, which was placed on two pegs in the center of the black background, was

disclosed when the curtain to the box was pulled back by means of a cord at the right. Light was thrown on the block from above, and diffused by the use of milk glass. The apparatus for the stimulus and the response are pictured in figures 4 and 5 respectively.

When the child was brought into the room and seated, he was told, "I am going to show you something in here (pointing to the curtained box), and I want you to look at it very closely, so that

Fig. 4. Apparatus for Stimulus Presentation in Experiment II

the next time you come into this room you can show me one just like it." The curtain was then pulled, and closed after 5 seconds by releasing the string and thus permitting the weighted curtain to fall back into place. The child was then told to return to his play group. All questions pertaining to the stimulus given were answered as noncomittally as possible. When the stimulus was presented, there were no blocks on the table. Although the child was not asked to give the name or make any overt response, many of the children pointed to the form and named it. The

child's attention, vocalization, and overt responses during the stimulation are functional parts of his delayed response, so that in case the child was asked to name or point to the block, those children who would do so of their own accord, would be deprived of an advantageous and spontaneously initiated memory aid.

For the response, the six blocks were placed on the table in front of the exposure box, which was now closed. The blocks were arranged differently each time, so that the child could not

Fig. 5. Apparatus for Response in Experiment II

use the placements of the blocks as a means of remembering the one seen in the box. When the child was brought into the room, after an interposed period of time had passed since the presentation of the form, and seated he was asked, "Will you point to the block that you saw the last time in this (pointing to it) box?". The child's problem was to discriminate between the blocks and to choose the sample seen the last time. This form of questioning was used in order to eliminate the neccessity of training in the mode of response. When the child had pointed, the experi-

menter said, "That is fine," and the child left the room. In this situation, the child had no means of knowing whether or not his response was correct, and the behavior was, accordingly, different from that observed in the first experiment, where failure to find the animal cookie was sufficient evidence of the inaccuracy of his choice.

The children's reactions to the experiment. The reactions of the children to the experiment with familiar forms were considerably different than to the first experiment. The problem was somewhat more difficult for them to understand, and the response differently motivated than when it was necessary to remember the position of a concealed object. In spite of this, each child made an effort to remember the block seen in the exposure box, and appeared to be just as much interested in pointing out this block in the response situation as in finding the reward in the former.

The delays obtained in this experiment were the least satisfactory of the four experiments. During the months when these familiar forms were used as stimuli, there were many absences, and it was impossible to carry out many of the predetermined delays. In such cases, the child was permitted to respond when he returned to school, rather than permitting the trial to be incomplete and giving a new stimulus. In view of the results obtained, the latter procedure would certainly have given more successful responses than the method used.

Since the experimental room in this situation was on the same floor as the children, and the time which the children remained there was very short, there was little opportunity for observing significant differences in the children's behavior. Aside from a few comments made about the operation of the exposure box, the vocal responses of all of the children were almost stereotyped.

When the object was shown in the box, each child, with a very few exceptions gave the object its appropriate name, and continued looking, smilingly, at the form until the curtain was closed after a five seconds exposure. After about the third trial, several of the children would look at the object for three seconds, and then look intermittently at the experimenter and the form. At any time during the presentation of the stimulus, some children

would ask such a question as "How do you open it?", "Where is the string you pull it with?", "Why do you put a cat there?", "Let me open it," "Where does the light come from?", or "Let me see it dark." Most children, however, did not deviate from the prototype: naming the object as soon as it was seen, and looking at the object during the entire exposure period.

When the six forms from which the child was to choose the one he had seen the previous time were placed on the table, the behavior was a little more varied for individual children. The usual response was, "This one," or naming the block and pointing to it. Most of the children pointed to a block immediately, and exhibited no less hesitancy when the response was incorrect than when it was the form they had actually seen the last time in the box. Several of the children hesitated in choosing, saying, "Let me think now," and after a short pause would usually point to the correct form. A few of the children did not remember, and did not select a form.

Quantitative results. A clear concept may be gained of the children's responses by a quantitative consideration of the results obtained. In tabulating the frequencies for the various responses to each of the six stimuli, the most striking fact about the data was the great number of incorrect responses. The percentage of each type of response given to each stimulus is presented in table 8.

It may be noted from this table that the only stimulus which was responded to correctly in any way approaching half of the times it was given as a stimulus, was the kiddie car. This form was used in the first trial on delay, and both because the first trial in a new situation appears to have the greatest mnemonic value and because there were no conflicting previous stimuli to influence the choice, there were more correct responses to the kiddie car than to any of the other stimuli used. The test for determining the familiarity of the forms was given at least one month previous to the first trial with a delay, and since at that time so many forms had been seen, there was little possibility of the memory for any one of them to have been sufficiently great to obliterate a much more recent stimulus viewed with greater attention. After

the first trial, there was a marked tendency to choose the kiddie car, despite several intervening stimuli. It was noted, further, that when there was any marked hesitancy in the response, the child usually chose the kiddie car or the cat, which was responded to accurately in the next largest proportion of cases, and which was used in the second delayed response trial. On the fourth trial, child 20, when the experimenter asked him to point to the one he had seen the last time in the box, said, "I can show you everyone of them." Undoubtedly, the rather frequent succession of stimuli, and seeing the six blocks used at all of the response parts of the trials tended to confuse the child, and to

TABLE 8

The frequencies of the stimuli and the responses in percentages for the various blocks in Experiment II

STIMULUS	TOTAL NUMBER OF TRIALS	RESPONSES IN PER CENT OF THE TOTAL						
		Kiddie car	Cat	Boy	Rabbit	Pig	Auto	None
Kiddie car	28	**46.4**	17.9	21.4	7.1	7.1		
Cat	29	27.6	**38.0**		10.3	6.9	10.3	6.9
Boy	23	13.1	17.3	**26.1**	8.7	13.1	17.3	4.4
Rabbit	20	5.0	25.0	10.0	**35.0**	10.0	10.0	5.0
Pig	14	21.5	35.7	7.1		**21.5**	7.1	7.1
Auto	6	16.7		16.7		50.0	**16.7**	
Totals	120	24.2	25.0	13.3	11.7	12.5	9.2	4.2

make him unable to discriminate between the one form seen the previous time, and ones that had been seen at one time or another previous to the present trial.

This confusion was seriously aggravated by the short intervals between trials in comparison to the lengths of the delays used. The two children who were given preliminary trials in memory for these forms were, apparently, little disturbed by the conflict due to frequent stimulation, so that in generalizing from their reactions to the experiment, the necessity of long intervals between the response for one trial and the stimulus for the succeeding one was underestimated.

The predominance of negative results in the memory for famil-

iar forms was due to the inability to discriminate the last stimulus object from other forms seen, but this could have been obviated to a great extent by increasing the intervals between the trials. The proportion of correct and incorrect responses in relation to the length of the interval between trials may be seen from table 9.

From the original data it was gathered, that only in the shorter delays were the intervals between the trials considerably longer than the delays. For the delays over ten days, practically all of the intervals were less than one-half of the length of the succeeding delays. Due to the tendency mentioned previously to

TABLE 9

The proportion of correct and incorrect responses for various ratios of the interval between trials to the length of the succeeding delay in Experiment II

INTERVAL ÷ LENGTH OF SUCCEEDING DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT	PER CENT OF WHOLE GROUP
0.0–0.4	50	34.0	66.0	53.9
0.5–0.9	12	25.0	75.0	12.9
1.0–2.9	11	36.4	63.6	11.8
3.0–9.9	7	14.3	85.7	7.5
10.0–19.9	7		100.0	7.5
20 and over	6		100.0	6.4
Totals........	93	26.9	73.1	100.0
First trial....	27			

remember *a* block previously seen rather than *the* block seen in the present trial, these intervals were obviously of insufficient length to obtain reliable values for the length of the delay possible for individual children.

The incorrect responses, however, increase with the increasing ratios of the interval between trials to the length of the succeeding delay. This would appear to be contrary to expectation, if the confusion among stimuli and hence the incorrect response is taken to be a result of this low ratio. This increase is due to the length of the delays included in the various groups. The higher ratios predominated in the shorter delays. These were given to

the younger children who failed to make more than a few correct responses. The nature of the responses after various periods of delay may be gathered from table 10.

Approximately one-third of all of the delay trials were responded to correctly, the remaining two-thirds, incorrectly. There was little difference in the length of the delays used as to the proportion of success in the responses, but this has no significance apart from the fact that it indicates that the delays determined upon were too long for all of the subjects in the experiment, and under the circumstances which the trials were given.

TABLE 10

The proportion of correct and incorrect responses after various periods of delay in Experiment II

LENGTH OF DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT
days			
1–3	33	30.3	69.7
4–9	10	40.0	60.0
10–14	47	37.5	62.5
15–20	12	41.7	58.3
21–29	10		100.0
30 and over	8	37.5	62.5
Totals............	120	30.0	70.0

The inadequate number of cases included, and the conflicting results obtained in this experiment do not permit of many generalizations. The method used, with some modifications, would lend itself well to measuring the delayed responses, especially of the younger children. The method of reaction could be taught, and if proper intervals were introduced between trials, the results would indicate the length of time that a child could remember certain forms. A comparison could be made of the comparative ease of naming a block seen, and selecting it from a group of stimulus objects.

Case studies. The records of individual children are not as valuable in this experiment as in the experiment with the hiding of the animal cookies. However, cases have been selected which

illustrate correct memory after relatively long delays, inability to distinguish immediately preceding and other previous stimuli, and typical reactions of a child unable to comprehend the purpose of the experiment.

Child 21

This little boy cooperated very well in all of the experiments, seemingly making a great effort to remember the stimulus given. He made an accurate response in all of the four trials given him, obtaining a maximum delay of 34 days when he was 59 months old, with a mental age of 88 months. He looked very closely at the object in the exposure box, in the first trial, and smiled when the curtain was closed. In the fourth trial, when he was brought into the room for the stimulus, he said, "I know what it is going to be." After he had been shown the form he smiled, nodded his head and said, "I knew, I knew." In this instance he was referring to the stimulus to be shown to him in the box, not to any definite stimulus object. In the responses after the first trial, he showed a slight hesitancy in choosing the object he had seen, but in each case he made a correct selection. In the second trial he said, "I've forgotten which one it was," but after a pause pointed to the cat. The experimenter said, "That's fine," and he replied, "I thought that was the one." In the next trial, he looked at the forms on the table a little while, and then pointed to the correct form, voicing at this time no uncertainty in his choice. In the last trial, he said, "I don't see it," but looked at all of the blocks again, and pointed to the correct block saying, "I think this is it, but I'm not sure." He displayed a critical ability in his selections far superior to the average child of his age. His concentration upon the stimulus, and his high intellectual level account for his ability to remember the object seen longer than any of the other children tested. The fact that he was able to select the correct forms in spite of rather frequent trials and inadequate intervals indicates further, his excellent ability to make this type of delayed response.

Child 32

This case illustrates, very well, the perseverative effect of previous stimuli and responses. In the first trial, he looked at the box during the entire five seconds of the stimulus time, saying nothing to the experimenter. After one day, he pointed to the correct form immediately, offering no comments whatever at this time. The next day, he was

shown another form, and upon seeing this he said, "What did you put a cat in this time for?" After a 17 day interval, in the response situation he pointed immediately to the kiddie car, which had been the correct response in the previous trial. Unquestionably, the object of the stimulus and the response in the previous trial had a greater mnemonic value for this child than the single stimulus, especially since there was an interval of only one day between the response of the first trial and the stimulus for the second. In the third trial, he responded correctly after an interval of 14 days, at which time he was 51 months old, and had a mental age of 58 months. When shown a rabbit he said, "Isn't that cute?", and when shown the auto said, "That's a cute thing. That is better than anything else." He did not make an accurate response in

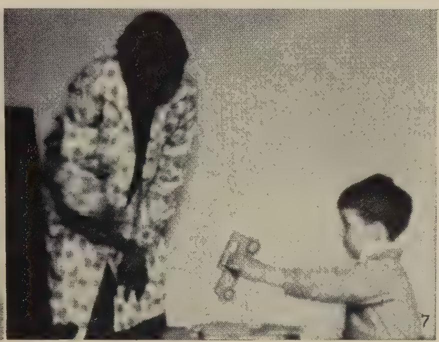

Fig. 6. Presentation of Stimulus in Experiment II

Fig. 7. Response in Experiment II

either of these two trials. In the last trial he unhesitatingly chose the kiddie car. The first stimulus was certainly the dominant one of all those given.

This child is looking at the auto in the exposure box in figure 6, and shown handing the car to the experimenter in figure 7. When these pictures were taken, the child was asked to give the object he had seen in the box to the experimenter, in order to obtain a better picture of the form he selected.

This child's mother reported that this game was played at home with the child acting as the experimenter, and the mother as the subject. These directions were given, "Do you see these marbles, and see this marble in my hand? Now you show me one just like it." There was not any like it, so the child said, "Just pretend they are alike."

Child 55

Although this child could point to and name accurately the six forms used in this experiment, he was very much confused in his responses to the absent stimuli after short periods of delay. The fact that he said, "This one," and picked up the correct form in the first trial, showed that he could remember the object after one day, provided there were no conflicting stimuli. He appeared to have a preference for the pig, pointing to it incorrectly in three successive trials. He responded incorrectly with boy in the following trial. His language ability is well illustrated by this sentence spoken to the experimenter when he met her in the hall, "I am bringing this picture downstairs for Miss K.—'s children." A pig was shown in the next trial, and after two hours he was brought back to the room for the response. He was asked, "What did you see in the box today?" and after a little pause he answered, "Pig." The objects were then disclosed by removing a cloth cover which had been placed on the table over the forms, and he was asked to point to the one he had seen in the box. He then pointed to the cat, and the kiddie car, and when the experimenter said, "I thought you said that you saw a little pig," he pointed to the rabbit. In the response for the following trial, he pointed to the pig, which was incorrect for this trial. This record demonstrates the great difficulty of a multiple choice situation for the younger children, since there are so many conflicting elements in the whole pattern of stimulation.

Summary. Delayed responses to exposures of familiar forms were obtained on 27 children who were given a total of 120 trials. The proportion of stimuli responded to correctly after an interval of time had elapsed since their presentation varied from 46.4 per cent in the case of the kiddie car, to 16.7 per cent when the auto was used as the stimulus. Seventy per cent of the stimuli given were responded to incorrectly after the delays introduced. This percentage differs little for the various lengths of the delays tried. The increase in the proportion of incorrect responses as the ratio of the interval between the trials to the length of the succeeding delay increases is misleading. The trend in these percentages is due to the nature of the length of the delay periods included in the different groups, not to this increasing ratio. The conflicting effects of previous stimuli and the immediately preceding stimulus seriously detracted from the reliability of the

delayed responses obtained in this experiment. The anticipated difficulty of this multiple choice situation using familiar forms as stimuli was not realized, because the maximum delays obtained had exactly the same range, namely one to 34 days, as those in experiment I, where delayed responses were made to the position of a concealed object. The confusion of the stimuli given in successive trials, and the complications introduced by the language associations involved, necessitated a further modification of this method in order to secure ever shorter maximum periods of delay and to avoid the effects of the marked perseverative tendency manifested in so many of the delayed responses in this set-up. The applicability of the general procedure, however, led to the choice of geometric forms as stimuli, since these were assumed to be more difficult to distinguish and remember than the familiar forms employed.

III. Delayed responses to exposures of geometric forms

Experimental procedure. The same apparatus was used in this experiment as in the preceding one, except that the test objects in this case were geometric forms, the names of which appeared to be unfamiliar to the age groups tested. The materials for this experiment are illustrated in figures 8 and 9. The six forms: square, triangle, diamond, cross, star, and circle, were chosen because they could be matched by the subjects of this experiment, in a preliminary test like the one in which familiar forms were used, but this time the children were not asked to name the blocks. It developed, however, that the children tended to give names to the forms according to an object that had a similar contour, and that a few of the children even knew the appropriate names for several of the forms. Both the presentation of the stimulus and the procedure for the delayed response were identical with those in the second experiment. Each block was shown, in a certain sequence in successive trials, in the large exposure box for 5 seconds. After a predetermined period of delay the child was brought back into the room and asked to point to the block he had seen in the box the last time. For the response the six geometric figures used in this experiment were placed directly in

front of the child on a small table, in an irregular order for consecutive trials. Following the conclusion of this experiment each child was asked to name the six blocks, and in case he responded, "Don't know," he was asked what it looked like, in order to determine, at least partially, the importance of the associative factor in the memory for the forms seen. In this test, the position of the form chosen in the response was also recorded, in order to provide a check on the frequency with which each posi-

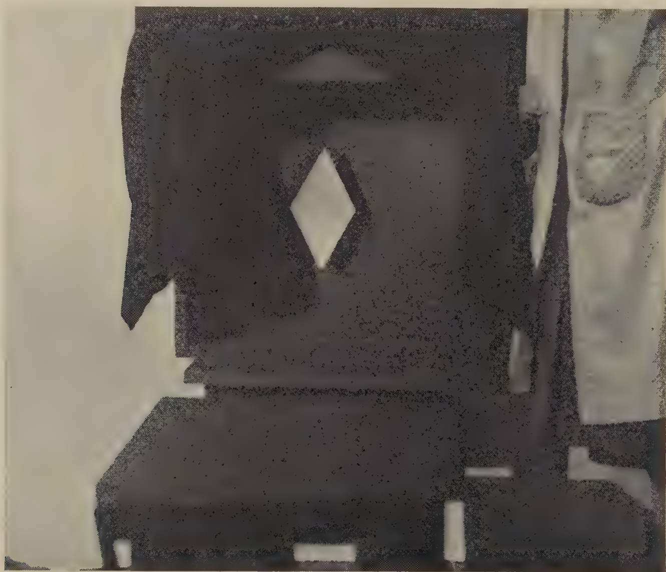

Fig. 8. Apparatus for Stimulus Presentation in Experiment III

tion was chosen, and to determine whether or not there was any preference for any of these.

Children's behavior during the experiment. In selecting geometric forms for stimuli instead of the more familiar objects used in the second experiment, it was assumed that the geometric forms would have less associations and hence could not be remembered for a very long time. The assumption proved to be true to a very great extent, since there was less tendency to name the blocks as they were shown in the exposure box, and no child

made a correct response if more than four days elapsed between the presentation of the stimulus and the response.

Since most of the children in this experiment had been subjects in the experiment with familiar forms, using the same exposure box, little curiosity was evinced regarding its operation when the geometric figures were used. Several children remarked about the change in the type of stimuli used. One child said, "I

FIG. 9. APPARATUS FOR RESPONSE IN EXPERIMENT III

thought it was a cat in there," and another child in the ninth trial with the geometric forms said, "Where are all the animals?"

Most of the children did not deviate from the following behavior in any of the trials. When the stimulus was shown, the child smiled, nodded his head or pointed to the form in the exposure box, continuing to look at it all of the time that the curtain was open. When responding, these children merely pointed to a block without giving any vocal response, or occasionally one would say, "This one," or name the form as he pointed to it.

In contrast with the behavior in the second experiment, there was little naming of the stimulus objects. A few of the children when viewing the stimulus object in the box, put their elbows on the table and rested their faces in their hands as if to concentrate better on the form. Typical individual differences in reacting to this experiment will be discussed in the analysis of special cases.

Quantitative results. Since more trials were given, and stricter attention was paid to the intervals between trials in this set-up than in the one with the familiar forms, the statistical analysis of the delayed responses to geometric figures is of greater value. The proportion of each type of response made in the

TABLE 11

The frequencies of the stimuli and the responses in percentages for the various forms in Experiment III

STIMULUS	TOTAL NUMBER OF TRIALS	RESPONSES IN PER CENT OF THE TOTAL						
		Square	Circle	Triangle	Cross	Star	Diamond	None
Square	52	**63.5**	15.4	3.9	13.4	1.9	1.9	
Circle	54	7.4	**68.5**	5.6	3.7	7.4	7.4	
Triangle	39	5.2	12.8	**58.9**	2.6	2.6	17.9	
Cross	39	12.8	5.2	2.6	**56.3**	5.2	17.9	
Star	36	5.6	8.3	13.9	13.9	**44.4**	8.3	5.6
Diamond	22	4.5	18.2	9.1		4.5	**63.7**	
Totals	242	19.4	24.4	14.9	15.3	10.3	14.9	0.8

trials when the different forms were used as the stimulus is given in table 11.

It will be seen that there was some confusion in discriminating between all of the blocks, due to inaccurate memory of the block seen the previous time in the exposure box. A great many of the erroneous responses were made to the triangle, cross, star, and diamond, since these were used as stimuli in the later trials, when longer delays were used, and the tendency to perseverative responses had a more appreciable effect. Aside from this effect due to previous stimuli and responses, there was a measurable failure to distinguish accurately between the square and the cross, the triangle and the diamond.

In order to discover individual differences in the familiarity of these geometric forms used, after all of the delay trials had been completed, each child was asked to name the blocks, the experimenter asking, "What is this?" as she pointed to each block lying upon the table. Since all of the children had matched the forms accurately in a preliminary test for familiarity, there was no question as to their ability to discriminate the forms. The three blocks given their appropriate names the most frequently were the star, square, and circle. Whereas the star was usually called a "star," the square was given such names as "table top," or "brick," about as frequently as it was called a "square," and the circle was often called a "moon," "ball," "wheel," or "ring," any one of which indicates that the form had some associative value for the child. The triangle was sometimes called a "house," or a "Christmas tree," the cross a "windmill," or a star with certain qualifications, and the diamond everything from a "fish" to "four squares."

The ability to name the forms does not correspond absolutely to the ability to remember them. In order to have tested the correlation, the forms would have had to be given in a different sequence for each child so as to test the memory for each form after various lengths of delay. As it was, the results in table 11 indicate that the star, which was used in the longer delays and was also named accurately in the most instances, was responded to correctly in the smallest proportion of the total number of times it was given as a stimulus. Since the diamond and the star were both used primarily in the longer delays, it is impossible to account for this difference in their associative values as determined by the children's ability to name these forms. It is further impossible to determine whether or not the high proportion of correct responses to the circle and the square was due to their familiarity or to the fact that they were used in the shorter delays. The solution of this problem, the relation of the familiarity of a form to the length of time that it can be remembered, is one which requires further study. The difficulty and hesitancy with which the geometric figures were named as an indication of their associative value, in contrast to the ease with which the

familiar forms in the second experiment were named, undoubtedly accounts in a large part for the great differences in memory for this type of stimulus.

A survey of the incorrect responses made when the geometric forms were used as stimuli yielded the results given in table 12.

The tendency to choose the form responded to in the previous trial was not as great as the tendency to respond to the plate where the animal cookie had been found in the previous trial in the first experiment. Although there was a noticeable influence of the previous response upon the present one, the primary reason for its not being more marked was that the response in the experiment with the geometric forms, with the choice from a sample, was not recognized as right or wrong by the child, and

TABLE 12

An analysis of the incorrect responses made in Experiment III

INFLUENCING FACTORS IN THE 97 INCORRECT RESPONSES	PER CENT
Form responded to in previous trial	33.0
Position responded to in previous trial	13.4
Seen or responded to at some previous time	23.7
Seen at the previous trial	9.3
Not seen or responded to before	18.5
No response made	2.1

that there was no reward given for a correct response, which would tend to increase the intensity of the stimulus. Only 20 per cent of all of the responses were made to a form neither seen or responded to in some previous trial. In the later trials there appeared to be a greater inability to make a correct delayed response, when it became increasingly difficult for the child to distinguish between several recent stimuli and the most recent one. Occasionally, an incorrect response was made which would have been correct in the previous trial, which trial had also been responded to incorrectly. It is possible that the child might have remembered that he had seen that block and did not remember having pointed to it in any response trial, and hence pointed to it in this last trial in spite of a later stimulus.

The six blocks for the response were placed on the table in front of the child, in two rows and were numbered from left to right in each row. There was manifested, on the part of some of the children, a distinct tendency to point to the block in the same relative position to the others as the block pointed to in the previous trial or trials. Whether this was a motor habit, a motor memory, or simply a convenient place to point to in case the form shown had been forgotten, it is difficult to say except in a study of individual cases.

The proportion of correct and incorrect responses to the various positions is given in table 13. In this table, as well as in all of the others, in the few cases where more than one form was

TABLE 13

The proportion of correct and incorrect responses for the various positions in Experiment III

POSITIONS	TOTAL NUMBER	PER CENT CORRECT	PER CENT INCORRECT
No response	2		100.0
1	41	70.7	29.3
2	49	69.4	30.6
3	46	78.3	21.7
4	39	66.7	33.3
5	36	25.0	75.0
6	29	38.0	62.0
Totals............	242	59.9	40.1

pointed to, only the first selection was considered in order to avoid duplication in the tabulations.

When the forms in positions one, two, three, and four were responded to, the selections were correct in over two-thirds of the trials in each case. On the contrary, when the forms in positions five and six were pointed to, the responses were incorrect in 75 and 62 per cent of the trials respectively. The tendency to point to these positions was noted in the early trials, and in order to avoid as much as possible the selection of the correct form because it was placed in the most favorable position, and increase the child's probability of making a correct response without memory for the form seen in this trial, these two positions were

used very little as the position for the form which was the correct response. The tendency to point to these forms which were nearest to the subject and readily accessible to his right hand might easily be explained on the basis that they were the most convenient responses, position five being more so than position six.

In this experiment the trials were spaced more in accordance with the lengths of the delays used than in the two previous ones. The maintaining of a large ratio of the interval between trials to the length of the succeeding delay was more closely adhered to in the shorter delays than in the longer ones, however. In

TABLE 14

The proportion of correct and incorrect responses for various ratios of the interval between trials to the length of the succeeding delay in Experiment III

INTERVAL ÷ LENGTH OF SUCCEEDING DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT	PER CENT OF WHOLE GROUP
0.0–0.9	21	23.8	76.2	10.3
1.0–2.9	32	34.4	65.6	15.6
3.0–9.9	33	60.6	39.4	16.1
10.0–19.9	14	64.3	35.7	6.8
20 and over	105	68.5	31.5	51.2
Totals........	205	57.1	42.5	100.0
First trial....	37			

table 14, are given the proportions of correct responses for the various ratios of the interval between trials to the length of the delay.

With increasing ratios, the proportion of correct responses increases from 23.8 per cent when the ratio is less than one, to 68.5 per cent when the ratio is over 20, that is the interval between the trials is over 20 times the length of the succeeding delay. This increase in the percentage of correct responses is due not only to the increased interval between the trials, lessening the perseverative effect of previous stimuli and responses, but also to the greater number of correct responses in delays of less

than one day, which are also the delays that are preceded by the comparatively long intervals. Unless the ratios are approximately constant for various lengths of delays, it is not possible to determine their effect upon the nature of the responses.

About one-tenth of the intervals were less than the length of the succeeding delays, while about three-fourths of the intervals were over three times the length of these delays. In over one-half of the trials, the intervals were more than 20 times the lengths of the delays after the interval used in computing the ratio.

The proportion of responses that were correct after various periods of delay is given in table 15.

TABLE 15

The proportion of correct and incorrect responses after various periods of delay in Experiment III

LENGTH OF DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT
0–59 minutes	105	52.9	47.1
60–119 minutes	35	88.5	11.5
2–5 hours	19	94.4	5.6
1 day	23	56.6	43.4
2 days	39	33.3	66.7
3 days	7	28.6	71.4
4 days	9	44.4	55.6
5 days and over	5		100.0
Totals............	242	59.9	40.1

No consistency is portrayed in the change in the percentages of correct responses after various periods of delay. It is necessary to consider each group by itself, since the trials included in each largely account for the percentages obtained. In the first group are included the trials of several children who failed on almost all of the delays given, all of which were less than one hour. Also many of the responses in the first trial, in which the delays were usually very short, were incorrect because the child had not quite understood the experiment. In the later trials, when the delays were much longer than one hour, correct responses were made by many of these children. In the delays of from one to five hours are included the trials on those children who both could and could

not remember a day, but could remember longer than one hour. If a child could remember one hour, it was probable that he could respond correctly at any later time during that same day, although he might not be able to respond correctly the next day. The children whose maximum delays fell within the range of from one to five hours could, perhaps, have remembered several hours longer, but due to the nature of the nursery school hours, the variety of the delays used was considerably limited. The percentage of correct responses decreases with the increasing length of the delays with the exception of the four day delay. However, the groups above two days, included too few trials to permit of any generalizations. None of the children in the group tested could respond correctly if a delay of more than four days was introduced between the presentation of the stimulus and the response.

Case studies. In non of the four experiments was so much variety displayed as in the reactions to this experiment. The cases selected illustrate responses to the situation using geometric forms as stimuli, types of comments made during the experiment as an evidence of the understanding of the situation, the perseverational effect of a previous correct response or a previously responded position, the naming of all the stimulus objects as they were presented, and the inability to understand the purpose of the experiment.

Child 21

The record for this child is typical for approximately half of the children used as subjects in this experiment. In the eight trials given with geometric forms as stimuli, he did not deviate from the following behavior, except in minor details: looking at the form, smiling, and nodding his head when the stimulus was given, and likewise in the response situation, pointing immediately to one form with no comments. He obtained a maximum delay of two days when he was 61 months old and had a mental age of 90 months. When asked how he remembered these forms he said, "I look at them a while, then I think about them so that I can remember them."

This child is shown looking at the triangle in figure 10. In figure 11 he is giving the block to the experimenter rather than pointing to it, as

was requested in the regular experiments, because it was thought that the selected block would be more clearly shown in the picture.

Child 33

No child expressed his ideas about the experiment as freely as did this boy. When he was shown a square in the first trial he said, "Block. I used to play a different game with little rabbits and all kinds of toys. Now it's different." He responded correctly after a delay of 30 minutes saying as he pointed to each block on the table, in turn, "Next time one like this, and this, and this. The star is almost like a cross except that they are different. I know what a star is. Is there one in there?" as he pointed to the exposure box. When the circle was shown him he

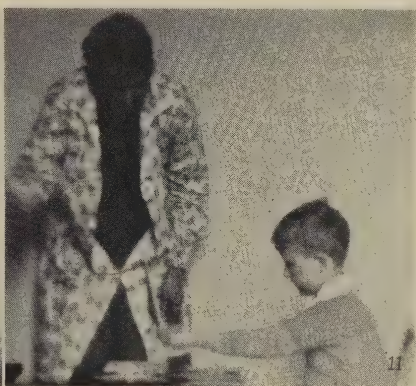

Fig. 10. Presentation of Stimulus in Experiment III

Fig. 11. Response in Experiment III

said, "Moon. A moon's like a circle isn't it?" In the response he pointed to the circle and then picked it up, waving it about before placing it back on the table. When he was shown a cross, he called it a "square," but said, "No, this way and that," as he motioned his hands like a cross. After having responded accurately with a square in the last trial, he placed the corner of the square to fit in between the intersections of the cross and said, "Look, they fit like this." His maximum delay of 4 days was obtained when he was 54 months old and had a mental age of 66 months. His vocal responses, unquestionably, strengthened the stimulus and enabled him to respond after longer periods of delay than most of the other children.

Child 23

This child responded correctly in all delays attempted up through four days. His behavior was practically the same as that described for child 21 on page 56, except that this child did not nod his head when the stimulus was shown. This case is described because it gives an excellent illustration of the perseverative effect of a previous response. In the sixth trial, he responded correctly after a four day delay by pointing to the square, when he was 59 months old. Three days later he was given the circle as a stimulus. In the response to this trial, after a delay of five days, he pointed very slowly to the square. The interval between the trials had been too short for the intervening stimulus to overbalance the mnemonic value of the stimulus and the response in the preceding trial. The hesitancy in the choice of this last trial was in marked contrast to the immediate selections in all of the previous trials.

Child 47

This was the only child who showed a consistent tendency to respond incorrectly to the same position each time. She looked closely at the form each time that the stimulus was given, but pointed to the block in position five in the first four trials, regardless of the form that was placed there. In the fifth trial, she responded correctly after a five second delay. Six days later, she resumed her response to the form in position five after a five minute delay, but changed her choice and pointed to the form in position one, which was the correct response for that trial. In the next trial, she pointed smilingly to the correct block which was in position four, having then gained an understanding of the test. It was unfortunate that no further trials could be obtained on this child due to her absence for the remainder of the experimental period.

Child 43

This record is illustrative of the attempt made to name all of the forms seen, even though this performance was not requested. She named all of the familiar forms when they were presented as stimuli in the second experiment, which reaction was probably carried over to this situation with the geometric figures. A triangle was called a "Christmas tree." When she was shown the circle she said, "A nice little, nice little, nice little," the curtain was closed and she added, "thing wasn't it? It was a moon wasn't it?" The best thing she could call the square was, "A little, a little air." When asked to name the

square in the final familiarity test she called it "sky." A cross was designated as a "butterfly," a star a "scramble," and a diamond a "house," when these were used as stimuli. She responded correctly to the star after a delay of two days, when she was 46 months old, and had a mental age of 62 months.

Child 24

This child likewise manifested a tendency to name each form, but her expression took a somewhat different turn than those described for child 43. When given the first trial she said, "I want to stand this time," and as she left the room, "What's that down there?" pointing to the back stairway. A circle was called a "round one." When she was shown a cross she said, "Round one. It isn't, but I didn't know it so I said round one." In the response on this trial, she entered the room before the experimenter and upon seeing the blocks on the table, pointed to the correct block before the directions for the response were given saying, "I saw this one. I pointed before you knew it, didn't I?" When she saw a square she said, "It's a whole one. I couldn't tell you, so I said a whole one," and when a diamond was shown to her she said, "Round. It's different, but I don't know so I said round." In this last trial she pointed incorrectly to the circle saying, "I didn't know it." It seems very probable that calling the object round, even though at the time she recognized that it was not round, confused her thinking and made her point to the round one instead of the one she had seen in the previous trial. When she made a correct response to the star after a two day delay when she was 59 months old with a mental age of 69 months, she said to the experimenter's "That's right," "How do you know if I get it right?" The experimenter had unwittingly said "right" instead of "fine." She was answered that the experimenter had it written down. She pointed to the blocks on the table and said, "Sometimes it is this, and this, and this," as she pointed to the triangle, the star, and the square. From her expressions it appeared that she had a better conception of the experiment as a whole and its purposes than any of the other subjects.

Child 52

This was the youngest child used in the experiment. Although he could match all of the forms in the preliminary trial, he failed to respond correctly in all but one trial, and the accurate response in this case was undoubtedly due to chance. His behavior was not different from that

displayed by any of the other children either in the presentation of the stimulus or in pointing to the form in the response, but his responses were invariably incorrect. Only a partial explanation can be given of this failure. The curtain to the box was opened, and he was asked to show the experimenter one just like the form in the box. He pointed to several saying, "This one, this one, and this one." The experimenter said, "But which one is most like the block in the box?" He pointed immediately to the correct form. In the following trial, however, when he was asked to point to the block the most like the one he had seen in the box he made an incorrect response. If more trials could have been given to this child, it is very probable that he would have learned to make the correct response in spite of the consistent early failures. When he was asked to name the forms after the last delay trial, he called most of them blocks, and when asked what kind of blocks he said, "To look at." He placed the star over the edge of the triangle and said, "This is a horse riding on a man." He called the star, further, a "goose," one of the points being designated as the "hanger." His record gives an inadequate basis for further interpretation of his continued failure to respond correctly in this situation after very brief delays.

Child 49

This child displayed some understanding of the test, but his reactions were incorrect in a majority of the trials. Although he responded correctly in three out of the first six trials, he did not respond correctly in any of the following nine trials, in spite of delays of similar length. The maximum delay obtained for him was ten minutes, using the star as a stimulus, when he was 46 months old. Since the trials were well spaced, and the child could match each of the forms correctly in both the preliminary and final familiarity test, the only explanation that can be offered, especially in the light of the correct response in the earlier trials, is that the child became so confused when he was given a great many trials that he could not remember the order of the stimuli. He was always eager to come with the experimenter, usually laughing heartily each time that the stimulus object was exposed in the box. It was not until the fifteenth trial that he showed any curiosity concerning the operation of the exposure box, "Have you got a rubber band in there to pull?" In the last trial, he asked to put his finger in the box, and when he was permitted to do so, he went up to the box, pounded at the square, and then said, "What's attached on there?" He seemed surprised that

it had not fallen out. This child would certainly have profited by a training series beginning with shorter delays always responded to correctly, and increasing to longer ones.

Summary. Delayed responses to exposures of geometric forms were obtained on 37 children who were given a total of 242 trials. The stimulus responded to correctly in the greatest proportion of trials was the circle, and in the least proportion, the star. This was not due, primarily, to differences in the familiarity of the two forms or in ability to discriminate between these and the other forms employed, but to the fact that the circle was used in the shorter delays, and hence was remembered in more cases than the star, which was used in the longer delays. There was less tendency to respond to the block or position responded to in the immediately preceding trial than was noticed when familiar forms were used as stimuli. This was due, undoubtedly, to the longer intervals between trials than was the case in the second experiment. The blocks in the two positions immediately in front of the child, and to his extreme lower right were pointed to incorrectly in the majority of the trials, whereas when any of the four other positions were pointed to, the response was correct in over two-thirds of the trials included in each group. About three-fifths of all of the stimuli given were responded to correctly in this experiment. There was a distinct increase in the proportion of these correct responses when the interval between trials in relation to the succeeding delay was large. The studies of individual children illustrate typical and exceptional delayed responses to geometric forms.

The maximum delays obtained in this experiment, ranging from ten minutes to four days were about one-tenth as great as those obtained in the two previous experiments, but this decrease was not as great as that desired. Since the decreased familiarity of these forms undoubtedly accounted in a large part for the decrease in the period of the maximum delays obtained, it was believed that if forms having even less associative value were selected, the delays could be further decreased.

IV. Delayed responses to exposures of unfamiliar forms

Experimental procedure. Six symbols were chosen for stimuli from those used in the Johns Hopkins substitution tests, because they could not be appropriately named by either adults or children. Each of the six figures were pasted on a card $3\frac{1}{2}$ by 3 inches. For the response situation, the six forms, each used at different times as the stimulus, were pasted on a card 5 by 8 inches, in two rows about two inches apart. A response card is reproduced in figure 12. Three of these response cards were made in order to place the figures in a different arrangement for

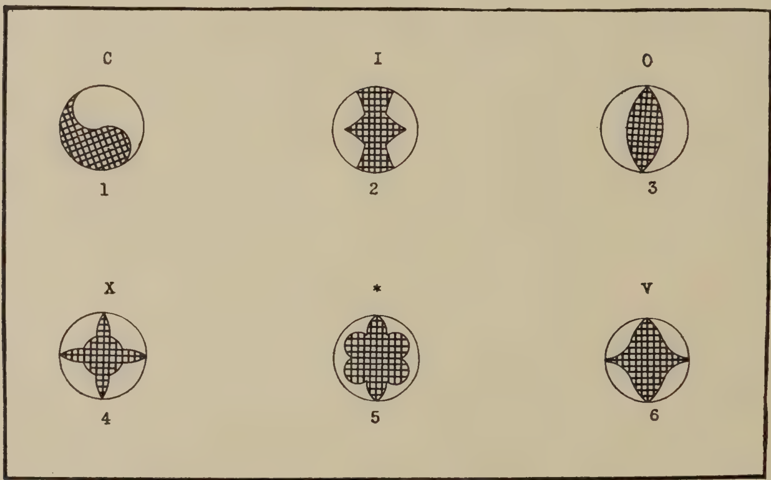

Fig. 12. Response Card for Experiment IV

each trial. Each of the symbols was given a letter or figure somewhat similar in its contour as indicated on the response card on this page, and will be referred to as such in the tables and discussion. Although appropriate names do exist for these forms, they would have less associative value than suggestive letters and figures, so that they have not been included here. In the preliminary experiment, all of the children who were given this situation could point to the correct symbol when the card was held directly in front of them. (Only the children above three years old were included in this experiment.) In many cases,

however, the response was not as immediate as in the second and third experiments, since the children frequently looked back at the figure to be matched, in order to discriminate accurately between the various forms.

For the presentation of the stimulus, the subject was seated in front of a small table on which was placed a Whipple portable tachistoscope. The same verbal directions were used as those in experiments II and III. The shutter was opened by the experimenter who stood in back of the table facing the child, and was closed after 5 seconds. After a period of delay the child was brought back into the room, and seated in front of the table on which the closed tachistoscope was placed. This time, the large card containing the six symbols used in this experiment was placed in front of the box, and the child was asked to point to the figure he had seen in the box. After all of the trials had been completed, each child was asked to tell what each figure looked like, or of what it made him think. There was a marked hesitancy in naming these figures, in many cases the children responded, "Don't know," to several questions regarding the appearance of the forms. Their paucity of verbal and experiential associations undoubtedly accounts for the short length of time that these figures could be remembered by the majority of the children. This experiment lends itself better to the measurement of the effects of training and increased familiarity with the stimuli than any of the previous ones.

The anticipated difficulty of remembering these forms was not completely justified in the results obtained. The delays were much longer than those expected, and the behavior manifested was little different from that in the two previous experiments using the familiar and geometric forms as stimuli.

A great deal of curiosity was shown concerning the Whipple portable tachistoscope, which was used for exposing the stimulus symbol or form. Several of the children asked "to do it" or "to open the shade." Many of the children were a little startled the first time the shutter was opened, because of the noise made, but this did not disturb them in the subsequent trials. There was much less tendency to name the forms used than in the two

previous experiments. The usual behavior when the stimulus was shown was to point to it, or remain looking at it without any overt response, and simply pointing to the symbol in the response saying, "This one," to the question, "Which one did you see in this box the last time you were in here?"

Quantitative results. The proportion of the different responses to the various symbols used as stimuli in this experiment is given in table 16. The symbols to which the keys refer may be seen in the response card on page 62.

The number of times that each symbol was used as a stimulus was not very large for any one of them, but the proportions reveal some interesting features for further study. The two forms

TABLE 16

The frequencies of the stimuli and the response in percentages for the various symbols in Experiment IV

STIMULUS	TOTAL NUMBER OF TRIALS	RESPONSES IN PER CENT OF THE TOTAL					
		I	X	V	*	C	O
I	32	**62.6**	6.2	3.1	12.5	6.2	9.4
X	30		**80.0**	10.0		3.3	6.7
V	14		7.1	**50.0**	14.3	21.4	7.1
*	22		31.8	13.7	**45.5**	4.5	4.5
C	14			7.1	7.1	**85.7**	
O	9	22.2	11.1			22.2	**44.4**
Totals.....	121	18.2	28.9	12.4	14.0	17.3	9.1

responded to accurately in over 80 per cent of the cases were the X and C. The ones remembered the least frequently were the O and the *. The O was used in the longer delays and was, therefore, frequently responded to incorrectly, but the primary reason for the larger proportion of incorrect responses to the * was due to the difficulty of discriminating between it and the X. In the final test for determining the familiarity of these forms, each child was asked to name the symbols, and in case he responded, "Don't know," he was asked to tell what each form looked like. The hesitancy in naming and the refusal to name the forms at all in many cases, illustrated quite conclusively,

that naming the symbols played a very small part in the memory for them. The only two forms which were named appropriately, were the C, which was given names such as moon, bowl, snail, and top of a baby carriage, and the X, which was called a switch, airplane, windmill, cross, a star with a ball around it, and a pin wheel. This ability to name, together with the ease of discriminating these forms, accounts for the greater proportion of correct responses for these two stimuli than for any of the other four. Many of the children responded, "Don't know," to one or more of the stimuli saying, "I think it looks like something, but I can't name it," "I can't because I haven't seen it enough times," "They look like something, but I don't know what," or "They don't look like anything." Several children in attempting to name each symbol sometimes gave the same name to two of the forms. When this occurred, they were asked, "Are those the same?" and if the child aswered, "No," he was asked, "Then how are they different?" In most cases they responded, "Don't know," or "They aren't different," although they were able to match the two forms given the same name without the slightest hesitation. One child gave two forms the same name, but when asked if they were alike he said, "No, they are very different," but could not state any difference. Another child, in distinguishing between the V and the X, both of which she had called a "cross" said, "This (pointing to the V) has two thick and two thin, but this (pointing to the X) has all thin," referring to the projections. There was little uniformity in the names given to the other forms, although the * was called a leaf or a flower quite a number of times and the I was called a man by several of the children. The associative value of these forms was almost negligible, as was demonstrated by the children's failure or great hesitancy in naming the forms after having seen each one of them at least five times, either as a stimulus or on the response card.

The perseverative effect of the previous responses is of less importance in this experiment than in any of the other three, as may be seen from table 17.

Of the 44 incorrect responses to this experiment, only 2.3 per

cent were responses to the form in the same position as that in the previous trial. Almost two-fifths of the incorrect responses were made to a form which had not been given as a stimulus or responded to by the child before the present trial. Less than one-third of the incorrect responses were of a distinctly perseverative nature, that is, either to the form or the position responded to in the previous trial.

TABLE 17

An analysis of the incorrect responses made in Experiment IV

INFLUENCING FACTORS IN THE 44 INCORRECT RESPONSES	PER CENT
Form responded to in previous trial	27.2
Position responded to in previous trial	2.3
Form seen or responded to at some previous time	22.7
Seen in the previous trial	9.1
Not seen or responded to before	38.6

TABLE 18

The proportion of correct and incorrect responses for the various positions in Experiment IV

POSITION OF FORM SELECTED	TOTAL NUMBER	PER CENT CORRECT	PER CENT INCORRECT
1	20	50.0	50.0
2	22	54.6	45.4
3	19	68.4	31.6
4	21	76.2	23.8
5	15	40.0	60.0
6	24	83.4	16.7
Totals	121	63.7	36.3

The proportion of correct and incorrect responses to the various positions of the symbols as numbered on the response card in figure 12 on page 62, is presented in table 18.

By referring to table 18, it will be seen that there was less tendency to prefer any one position than was observed in the experiment using the large wooden geometric forms. Although there was a larger proportion of incorrect responses to the forms in position five, the difference between this percentage and the others is not great enough to be of any significance. All of the

forms for the response were on a card which was only 5 by 8 inches, so that pointing to one form required about the same amount of effort as pointing to any other one. The total proportion of trials that were responded to correctly in this situation was 63.7 per cent.

The trials in this experiment were very widely spaced for the most part, but especially for those delays which were shorter in length than one day. Very few of the trials were separated by less than the length of the succeeding delay. The proportion of correct and incorrect responses corresponding to the various ratios of the interval between trials to the length of the delays is presented in table 19.

TABLE 19

The proportion of correct and incorrect responses for various ratios of the interval between trials to the length of the succeeding delay in Experiment IV

INTERVAL ÷ LENGTH OF SUCCEEDING DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT	PER CENT OF WHOLE GROUP
0.0–0.9	7	71.4	28.6	7.6
1.0–2.9	10	70.0	30.0	10.8
3.0–9.9	10	80.0	20.0	10.8
10.0–19.9	3	100.0		3.2
20 and over	63	58.8	41.2	67.6
Totals........	93	64.5	35.5	100.0
First trial....	28			

Due to the nature of the distribution of the delays in the trials included in the various ratios, the percentages of correct and incorrect responses are in themselves of little value. These ratios would seem to indicate that the longer intervals are less desirable, as far as obtaining correct responses is concerned, than the shorter intervals. To a certain extent this may be true, since it was possible that the child might forget certain elements of the experimental situation if too long a time intervened between the trials, and thus predispose him to an incorrect response. This was especially true in cases where the child failed several times on the shorter delays given, perhaps on alternate days, whereas after he had attained a better idea of the test he made

correct responses after longer delays, with shorter intervals between the trials. Less than 20 per cent of the intervals were less than three times the lengths of the succeeding delays, whereas over two-thirds of the trials were given after intervals at least 20 times the length of these delays.

The proportion of correct and incorrect responses after various periods of delay is given in table 20.

There is no constant increase or decrease in the proportion of correct responses after increasing periods of delay. In the first group the percentage is lowered a great deal by numerous failures in the first trials which were, with a few exceptions, delays of less than 30 minutes. Most of the children succeeded in the second

TABLE 20

After various periods of delay in Experiment IV, the proportion of correct and incorrect responses

LENGTH OF DELAY	NUMBER OF RESPONSES	PER CENT CORRECT	PER CENT INCORRECT
0–29 minutes	55	58.2	41.8
30–59 minutes	30	70.0	30.0
60–119 minutes	15	53.3	46.7
2–6 hours	5	100.0	
1 day	13	76.9	23.1
2 days	3	33.3	66.7
Totals...........	121	63.7	36.3

trial given of less than 30 minutes, however, and often made successful responses after delays of more than one hour as well. The delays of from two to six hours were given to children who could not remember any of these symbols for one day, but very probably could have remembered one of these figures longer than six hours, providing the nursery school's hours had permitted such delays. Only one child in the group remembered these symbols as long as two days, although several perseverative responses occurred after periods of longer duration than this.

Case studies. None of the individual records gives a great deal of data on the child's memory for the forms in this experiment. Although the symbols in themselves were not a disturbing ele-

ment, the operation of the tachistoscope and the child's interest in obtaining permission to close or open the shutter tended to detract from the value of the experiment. There appeared to be little possibility of a decrease in this interest, in fact, the children seemed more and more curious about the box in each succeeding trial. Records have been selected for a more detailed description, which illustrate the typical responses to this experiment with the unfamiliar forms as stimuli, a consistent attempt to name all of the forms seen, the behavior of a very inquisitive child, and the effect of a variation of the stimulus upon the delayed response.

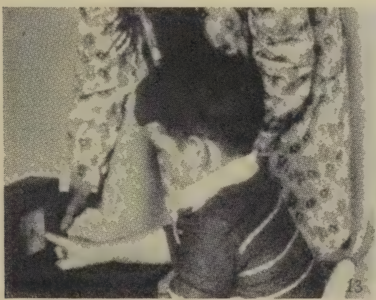

FIG. 13. PRESENTATION OF STIMULUS IN EXPERIMENT IV

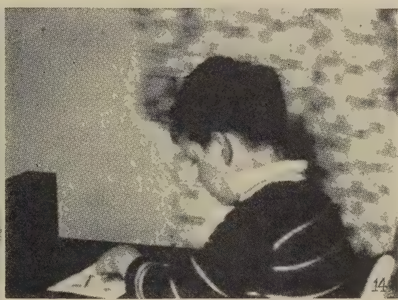

FIG. 14. RESPONSE IN EXPERIMENT IV

Child 29

This child's response during the whole experiment is typical for all of the children. When the stimulus was shown, she either pointed to it or simply looked at the symbol during the entire exposure time. She did not hesitate in pointing to the symbol in the response, one time even pointing to the correct form before the directions were given. Her maximum delay time was five and one-half hours, when she was 58 months old, and had a mental age of 61 months.

Child 32

A great deal of interest was manifested in this situation by this boy. He called two of the stimulus forms, "a funny thing," and "a thing that jumps." He wished to wind and open the shutter, but this was not permitted. On the second and third trials, he pointed to the correct

form before the directions for the response were given. He remembered the correct form after one day, when he was 54 months old, and had a mental age of 61 months.

The child is pictured looking at the form in figure 13, and pointing to the form seen in the tachistoscope in figure 14.

Child 43

This child was consistent in her attempt to name all of the forms seen in each of the three experiments employing forms as stimuli. When she saw the I in the tachistoscope she said, "A pretty . . . . piece of furniture." She called the X, "A b-b-building," and the *, "A sky, a house." Her maximum delay was one day when she was 49 months old and had a mental age of 62 months.

Child 27

An excellent example of a very curious and excitable child is illustrated in this case. In almost every situation in which the experimenter came in contact with this child, his chief question at all times was, "What is that?" In many cases he answered the question himself if no answer at all was forthcoming. He failed in his response on the first trial, after a delay of five minutes. Eight days later the C was given as a stimulus. When the shutter to the tachistoscope was left open and the response card was placed in front of him, he pointed to the correct form and said, "This is that." His attention now completely left the forms, and centered upon the box itself, "I want to open it." In order to study his behavior at greater length, the experimental procedure was dispensed with, and the following occurred. The experimenter wound the tachistoscope so that the last opening would occur when the lever was pushed down. The child was then permitted to close the shutter and wind the tachistoscope again. In attempting to close the shutter a second time, he turned a screw at the bottom of the box which had no connection with the shutter, but pushed the lever again, thus closing the aperture. It was only after some persuasion that the child would leave the room. When he was brought into the room two hours later he said, "I want to open it." When the directions were given he pointed immediately to the correct symbol, and turned his attention again to the tachistoscope. He was permitted to open and close the shutter as he had done two hours previously, and in doing so he saw the * which had been placed in the tachistoscope for stimulating another child. He saw this form sufficiently long so that it was regarded as a stimulus, and

justly so, because the child pointed to this form immediately one day later, when the response card was placed in front of him. Undoubtedly, the child's great attention and interest enabled him to remember the last form shown a day previously, whereas he failed in the first trial after a five minute interval. The fact that there was no interval between the response of the second trial and the stimulus for the third was more than compensated for in the type of stimulation received with the self-operation of the tachistoscope. This was not considered as a maximum delay since the stimulus pattern was very different from that given the other children, and hence the results were not comparable.

Child 16

After a maximum delay of two hours was obtained on this child when he was 65 months old and had a mental age of 82 months, the conditions of the stimulus were somewhat changed in order to see if this made any difference in the length of the delayed response. Instead of exposing the form for five seconds, the shutter in the tachistoscope was closed after one second's exposure of the form. The child remembered this form after a delay of one hour, and did not manifest any different behavior in either the stimulus or response situation than under the usual experimental conditions. It appears that if the stimulus time is long enough to give a clear picture of the form that, within certain limits, an extension of this time makes no appreciable difference.

Summary. A total of 121 delayed response trials were given to 28 children in this experiment where unfamiliar forms were shown. The I and the C (the forms which they represent may be seen in figure 12 on page 62) were each responded to correctly in over 80 per cent of the trials in which they were given as the stimulus. The final familiarity test indicated the inability to name any of the forms according to some similar object, except with a great deal of indecision and hesitancy. Less than one-third of the incorrect responses were of a perseverative nature, that is an incorrect response due to the persistance of the previous correct response. There was not such a distinct tendency to point to the forms in the positions nearest to the subject in this experiment, since all of the positions were about equally accessible. The maximum delays obtained in this test ranged from one minute to two days. No definite relationship was noted

between the ratio of the interval between trials to the length of the succeeding delay. The individual studies attempt to account, to some extent, for the great variation in the length of the maximum delays obtained by the different children.

This situation has not been adequately tested for its applicability to the measurement of delayed responses, but in view of the short delays obtained, it appears to be the type of measure desired. Suggestions for the further use of this test will be made in the final summary of this investigation.

TABLE 21

The distribution of maximum delays and chronological ages in Experiment I

MAXIMUM DELAY	CHRONOLOGICAL AGES IN MONTHS															TOTAL NUMBER
	24–26	27–29	30–32	33–35	36–38	39–41	42–44	45–47	48–50	51–53	54–56	57–59	60–62	63–65	66–68	
days																
34–36									1							1
25–27								1								1
22–24										1						1
19–21								1		1	1	2	2			7
16–18										2						2
13–15					1		1		1	1		2		1		7
7–9							1	1	1			1				4
4–6							3	2	2						1	8
1–3	1	1	3	4		2	1				1	1	1			15
Totals.	1	1	3	4	1	2	6	5	5	5	2	6	3	1	1	46

Maximum delays obtained. Although there were relatively few cases in each experiment on which maximum delays were obtained, Pearsonian coefficients of correlation were computed to determine the extent of the relationships existing between these delays as obtained in the various experiments and each child's chronological and mental age, and intelligence quotient. Since in each experiment, the chronological age was available for all of the children but not their intelligence quotients, the distributions showing the scatter of the maximum delays obtained in relation to each child's chronological age are given in tables 21, 22, 23, and 24. Apart from a consideration of the distribution of the cases, the coefficients are of little value, because the items are so unevenly apportioned.

The scatter diagram for the relationship between chronological age and the maximum delays in the first experiment is given in table 21.

The delays were divided into three day groups, but only those in which maximum delays occurred are given in table 21. None of the children under three years of age remembered the position of the concealed object after delays of more than three days. There were, also, a few children over three years who did not remember where to obtain the reward longer than three days, and some who did not make correct responses after delays over nine days in duration. The failure of an older child to respond correctly after delays of less than ten days was due in individual cases to such factors as poor attention, excitability, inability to combat the perseverative effect of previous responses, as well as poor "memory," if such it may be called.

There are duplicate entries for four of the children who obtained maximum delays in each of the two years that this experiment was given. These children were numbers 21, 32, 34, and 45. In each case there was an increase in the maximum delay obtained. This fact, as well as the relationship shown between increasing age and the maximum delays obtained, indicates that chronological age is an important factor in the ability to respond to an absent stimulus of this kind, after varying periods of delay. In the correlations given later, the chronological and mental ages are presented in relation to the maximum delays obtained for the two years, but the intelligence quotients are only correlated with the last delay obtained.

The distribution of the maximum delays obtained in the second experiment with the familiar forms used as stimuli, in relation to chronological age is given in table 22.

The distribution in this table indicates a more rectilinear relationship than that portrayed in table 21. Although the obtaining of maximum delays in this experiment was not very satisfactory, those that were obtained show a very close relationship to the child's chronological age. The limited number of cases included, however, permit of only a general statement, that the older children tend, on the whole, to remember a familiar form

seen longer than the younger children. With additional numbers the distribution would very probably be considerably different.

Although the experiment with the geometric forms was the most adequately tried out, and the delays the most certainly determined, table 23 indicates the absence of any relationship beween chronological age and the maximum delays obtained.

TABLE 22

The distribution of maximum delays and chronological ages in Experiment II

MAXIMUM DELAY	CHRONOLOGICAL AGE IN MONTHS									TOTAL NUMBER
	33–35	36–38	39–41	42–44	45–47	48–50	51–53	54–56	57–59	
days										
34–36									1	1
19–21				1		2			1	4
16–18						1		2	1	4
13–15							2			2
10–12				1	1					2
7–9								1		1
1–3	2									2
Totals...	2			2	1	3	2	3	3	16

TABLE 23

The distribution of maximum delays and chronological ages in Experiment III

LENGTH OF MAXIMUM DELAY	CHRONOLOGICAL AGE IN MONTHS										TOTAL NUMBER
	42–44	45–47	48–50	51–53	54–56	57–59	60–62	63–65	66–68	69–71	
4 days					1	2					3
2 days	1		2	1		1	1	1	1	1	9
1 day			3	2	1	1		1			8
0–6 hours		3		3		2		1		1	10
Totals.....	1	3	5	6	2	6	1	3	1	2	30

On the basis of this distribution it would be difficult to predict any child's possible maximum delay when his chronological age was given. If this experiment had introduced a training series that would have enabled the younger children to participate in this experiment, it is very probable that the relationship would have appeared somewhat closer than it does for these children in

the older age ranges. So many factors influence the delayed response aside from the memory for the forms seen that it is impossible, without further investigation, to give any adequate explanation of the great scatter in the distributions.

The experiment with the unfamiliar forms was the least completely carried out of any of the experiments, primarily because it was formulated after the results on the previous experiments pointed the way to the institution of a more difficult situation, near the end of the experimental period. The distribution of the maximum delays obtained in relation to the chronological age is given in table 24.

This table indicates the absence of any relationship between chronological age and the delays obtained using unfamiliar forms as

TABLE 24

The distribution of maximum delays and chronological ages in Experiment IV

LENGTH OF MAXIMUM DELAY	CHRONOLOGICAL AGE IN MONTHS								TOTAL NUMBER
	48–50	51–53	54–56	57–59	60–62	63–65	66–68	69–71	
2 days								1	1
1 day	2	1	1	1	1		1		7
0–6 hours	2	2		2		2		1	9
Totals....	4	3	1	3	1	2	1	2	17

the stimuli. The two oldest children in the group had maximum delays which fall in the highest and lowest classes respectively. The determination of the delays was not certainly established except in the cases of those below six hours, where more trials could be given to the same child. In spite of the nature of this distribution, it is very probable that more accurately determined delays would show a closer relationship to chronological age than is indicated by that given in table 24.

Even though a limited number of cases were included in the four experiments, coefficients of correlation were computed to discover the nature of any relationships that might exist among the delays obtained in the various experiments and certain other factors. Since the delays were very limited in their magnitude,

and so many cases occurred in each group, it was impractical to use the rank order method of correlation. The Pearsonian coefficients of correlation and their probable errors as presented in table 25 were obtained from the following formulae.

$$r = \frac{\frac{\Sigma\, xy}{N} - cx \cdot cy}{\sigma x \cdot \sigma y}$$

$$P.E. = .6745 \cdot \frac{1 - r^2}{\sqrt{N}}$$

Where, r = coefficient of correlation
x and y are the variates
cx and cy are the corrections for an arbitrary origin
σ = standard deviation
N = number of cases
$P.E.$ = probable error
Σ = sum of

TABLE 25

Correlations obtained between the maximum delays obtained by the children in the four experiments and their C.A.'s, M.A.'s and I.Q.'s

EXPERIMENT	CHRONOLOGICAL AGE			MENTAL AGE			INTELLIGENCE QUOTIENT		
	Number of cases	r	P.E.	Number of cases	r	P.E.	Number of cases	r	P.E.
I	46	+.478	.077	36	+.356	.098	32	+.212	.114
II	16	+.669	.093	13	+.751	.082	13	+.712	.092
III	30	+.134	.121	27	+.104	.128	27	−.271	.120
IV	17	+.185	.158	17	+.322	.147	17	+.312	.148

Since an unequal number of cases was used in finding the coefficients, this is also included for each case. The data presented in table 21, 22, 23, and 24 are the distributions on which the correlations for chronological age and the maximum delays are based. A somewhat questionable procedure was adopted with regard to determining the mental age used in these correlations. It was assumed that the intelligence quotient of a child remains constant, at least relatively so, and that although these intelli-

gence tests were given perhaps a month before or after the maximum delay was obtained, that if the chronological age at the time the child was stimulated for the trial on which the maximum delay was obtained was multiplied by his I.Q., there would be a limited amount of error in the mental age computed.

The correlations indicate that chronological age is the most important factor, on the whole, in determining the length of the maximum delay. Mental age is of more importance than the I.Q. in all of the experiments. The test using the familiar forms as stimuli shows the closest relationship to chronological and mental age and intelligence quotient in the maximum delays obtained. In this experiment, there was an insufficient number of cases to render this coefficient of any great value, except as an indication of a trend. The high correlation obtained for I.Q. and the maximum delay in this situation was due to the fact that the oldest children in this case had the highest I.Q.'s and hence the highest maximum delays.

Chronological age plays an unimportant rôle in determining the maximum delays in the experiments using geometric and unfamiliar forms as stimuli. The only negative coefficient obtained was between the maximum delay and the I.Q., using the geometric forms as stimuli. There was little relationship observed in the scatter diagram between these two factors, but the negative element was introduced largely by one case which had the highest I.Q. and whose maximum delay fell in the lowest class interval. Mental age appears to be a more important factor in the maximum delay in the experiment with unfamiliar forms than any of the other factors, but this correlation is too low and the probable error too high for it to be of any significance.

In case maximum delays were obtained in two or more experiments by the same child, these were used as the basis for determining the relationship existing between the tests. The coefficients and their probable errors are presented in table 26.

The number of cases in these coefficients of correlation are necessarily even more limited than where only the delays in one experiment were concerned. The only correlations indicating the existence of any relationship at all are those between

the delays obtained with concealed objects and familiar forms, concealed objects and unfamiliar forms, geometric and unfamiliar forms used as the stimuli. The others are of no significance except to indicate the absence of any relationship.

Very little weight can be attached to these coefficients either negatively or positively. Their smallness may be due to inadequate measures of the maximum delay, to a discrepancy between these factors and the maximum delay, or to both. It is certain that memory, as measured by these tests, is not any unit factor, but is dependent upon many conditions which may or may not be closely related.

No mention has been made throughout this study of the part played by sex in the ability to make delayed responses. Due to the difficulty with which the subjects could be secured, no attempt was made to select an equal number of girls and boys, either for the groups as a whole or at each age. Any comparisons made between the sexes or any further discussion of age differences in the maximum delays obtained in this study would be premature, not only because of the unequal numbers in each age and sex group, but because the results are of a tentative nature and primarily indicative of the applicability of these tests for measuring the delayed responses of young children.

TABLE 26

Correlations between the maximum delays obtained by the same children in the four experiments

EXPERIMENT	II			III			IV		
	Number of cases	r	P.E.	Number of cases	r	P.E.	Number of cases	r	P.E.
I	16	+.493	.128	17	−.252	.153	7	+.540	.181
II				13	+.122	.185	5	.000	.000
III							17	+.504	.122

III. SUMMARY

In this summary, an attempt will be made to review the primary results of the experiments, to discuss the interrelationships

existing, and to point out problems suggested by this study of the delayed response.

The situation testing memory for the position where an object was concealed proved to be an excellent test for the younger children, and for measuring the ability of the older children to make a correct response to an absent stimulus after long periods of delay. The maximum delays obtained in this experiment ranged from 1 to 34 days. The older children and those with the higher mental ages tended to remember longer than the younger children or those with the lower mental ages. Although this was valuable as a test of the length of time that a given stimulus could be responded to accurately after a given delay, it did not permit of any measurable variations due to the long delays obtained. The children's behavior and vocal responses offered some cues as to the manner in which the positions were remembered, and as to the nature of the relative effects of previous responses and the most recent stimulus upon the delayed response.

A marked perseverative effect of previous stimuli and responses when the familiar forms were employed was observed. This experiment, however, showed the closest relationship to the child's chronological and mental age. If the younger children were taught the method of response in this experiment, the test situation would provide an excellent means for measuring their delayed responses and the effect of variations in the stimuli. For the children who mastered the situation, the maximum delays varied from 1 to 34 days.

For the older children, either the geometric or unfamiliar forms are effective as stimuli in measuring the delayed response. The delays obtained were all below four days, and with certain limitations in the exposure and types of forms used, this maximum delay could perhaps be reduced to one day for the best reactors, and to several hours for a majority of the children. The importance of language responses in increasing the length of the delay after which a correct response would be made could very profitably be studied by the use of this method. The absence of any relationship between the maximum delays obtained in

these two tests and the chronological and mental age, and the I.Q.'s appears to be due to the complexity of the elements included in the situation, and to the limits used in determining the maximum delays. The responses to the two tests by the same child were very similar.

The field of measuring the delayed responses of young children is essentially a new one, and the development of methods of investigation was an important result of this study. From the experimental results obtained, it was readily determined that the children's ability to remember different sort of stimuli varied greatly. Modifications of the procedure, as well, provide great opportunity for measuring variations in the delayed response. It is very probable that if the child were permitted to hide the reward himself, or could expose the form in the tachistoscope, his delayed response would be very different from that observed when this was performed by the experimenter. Changes in the exposure time, varying from the least time in which the stimulus could possiby be seen, to 30 seconds or more, when the child would have become thoroughly bored with the situation, would probably give different types of delayed responses. Accessory stimulation such as telling the child to remember, promising additional rewards for success, permitting the child to make a response immediately after the occurrence of the stimulus merits study. In order to investigate further, the effects of unequal familiarity and associative values of the forms upon the delayed response, control experiments should be planned.

There is a question as to the perseverative effect which might occur in case two types of stimuli were used alternately in a series, for instance one of six geometric forms in one trial, and one of six others in the succeeding trial, then one of the first group, and so on, that might well be studied. Perhaps this method could be used instead of more widely spaced trials. The selection of forms in this case, however, necessitates a separate investigation in itself.

Grouping trials very closely together and testing the perseverative effects manifested without regard to the establishment of a maximum delay might be carried out in order to study the con-

flicting results of a recent stimulus and the earlier responses. The order of the trial series permits of much variation, as well. The younger children should be given a training series, enabling the use of multiple choice situations with them before this method is employed at two to three years.

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BY

ELLA MAY HANAWALT

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WHOLE AND PART METHODS IN TRIAL AND ERROR LEARNING

ELLA MAY HANAWALT[1]

CONTENTS

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[1] The writer desires to acknowledge her indebtedness to those whose counsel and coöperation have contributed to the success of the experiments described in this report. Especial thanks is due to Prof. J. F. Shepard who has assisted with materials and counsel throughout, to Prof. W. B. Pillsbury who has given advice, and to Prof. C. H. Griffitts who has reviewed the manuscript. This assistance is but part of a long-continued larger kindness which the writer has received from these teachers and friends at the University of Michigan. Much of the success of the experiments is due also to the coöperation of the members of the class in Advanced Comparative Psychology who have given liberally of their time and service in taking records.

I. HISTORICAL REVIEW

One of the questions in the psychology of learning which experimentation has thus far failed to answer satisfactorily is that of the relative effectiveness of whole and part methods of procedure. By whole procedure is meant repetition of the material to be learned from beginning to end without interruption as many times as is necessary for the learner to attain a given standard of accuracy. Part procedure involves breaking up the material to be learned into parts, repeating the parts separately until each is learned, finally putting them together again, repeating the whole until the learner has attained the given standard of accuracy in reproduction. These are the pure whole and the pure part methods. In addition to these there have been suggested certain "mediating" or "modified" whole procedures, forms of whole procedure which lie between the whole and part procedures as defined above; and "modified" part procedures, which to a greater or less degree approach the whole procedure in character. Whether the whole procedure or some modification of it, or the part procedure or some one of its modifications is the best procedure to use in learning any given material has thus far not yet been conclusively determined.

In the attempt to evaluate these methods experimental work was done during the early years of the present century by a number of European psychologists, chief among whom were Ebbinghaus (6), Steffens, (30), Pentschew (19), Ebert and Meumann (8), Ephrussi (9), and Neumann (15) in Germany, and des Bancels (1) in France. The types of learning included in the studies of these investigators are rote learning (nonsense syllables) and meaningful learning (prose and poetry). In their conclusions they all agreed that, for most materials, learning by the whole method is more economical than learning by parts. Some of them did suggest, however, that in the use of material in which there is much inequality in the difficulty of parts or in which the length is such that attention cannot be fairly uniformly distributed over the entire body of material, it may be of advantage to use a modified whole method. Two such modifications

of whole procedure are described by Meumann (13) as follows: (a) "The whole body of material is divided into parts, the basis of division being the degree of difficulty of content; and the parts are marked off by a stroke or a blank space. In reading the series the reader pauses for a short time at the end of each section but he does not then return to the beginning of the section; instead he continues to read through to the end as in the case of the whole procedure." (b) With non-coherent material, such as the vocabulary of a foreign language, "the reading of the series of words progresses continuously until the learner observes that certain members of the series prove to be especially difficult. These he indicates by a written mark; he devotes special effort to learning them and then returns to the reading of the whole series,—continuing until the whole is uniformly memorized." But the general conclusion reached by these early experimenters is best expressed by Meumann (13) in these words: "General psychological considerations as well as experimental findings show that the whole method is the only one which is psychologically justifiable and that it is by far the most economical. That is, the whole method requires fewer repetitions and usually less time than the part method to produce a first errorless recitation; and what is still more important, the whole method secures a more accurate reproduction and more lasting retention."

In recent years experimental study of the relative effectiveness of the part and whole methods of learning has been renewed by British and American investigators, but the conclusions reached have not been as uniform as was the case with the earlier German and French investigators. On the one hand, Pyle (21), Pyle and Snyder (22), Lakenan (12), Brown (3), Sawdon (26), and Crafts (5) as experimenters, together with a host of writers of textbooks in psychology and education, favor the whole method; while on the other hand, Pechstein (16, 17, 18), Reed (23, 24, 25), Barton (2), Koch (11), and Winch (31) regard the whole method as inferior, some of them attacking it with not a little vehemence. The types of learning included in the studies of the group favoring part procedure are rote learning (nonsense syllables), meaningful learning (poetry) and trial and error learning (typewriting,

maze learning). The general conclusion of this group has been that the part method or some modification of the part method is superior to the method of the whole.

Summing up the advantages and objections which have been suggested or indicated by various investigators of the two procedures, we have the following:

Advantages of the whole method:

1. There is better distribution of attention and effort, keeping all associations of approximately equal strength until the maximum of efficiency is reached (8, 30).
2. Learning proceeds continuously in a forward direction so that no special act of learning is required in order to master any transitional portion (13).
3. The wholeness or unity of pattern (Gestalt) present in consciousness gives the material a coherence and meaningfulness which aid in fixing associations (13, 19).
4. Associations are formed in the way in which they are to be used and in no other way—
   a. The association of each of the elements of the material in its proper relation, not only to the other elements, but also in its absolute position in the whole series, is retained and strengthened in each repetition (13, 30).
   b. Associations between the individual elements of the learning material are formed in the direction and only in the direction in which they are to function in later reproduction (13, 8).
   c. There are formed no unnecessary or incorrect associations which tend to interfere with the formation of correct associations (20, 30).
5. The rhythm employed is more suitable to the whole material (8).

Objections to the whole method:

1. There is confusion for the learner due to the fact that the length of the material exceeds his span of attention (23, 24).

2. For the learning effort expended upon the later portions of long material there are diminishing returns due to the fact that learning does not vary directly with the length of the material to be learned but that, rather, increasing the length of material increases disproportionately the difficulty of learning it (17).
3. The learner cannot readily see his own progress when he learns by the whole method (13).
4. There is waste of time caused by useless repetition of the known in order to master the unknown (24, 30).
5. Attention in the middle of the material, if long, tends to revert to earlier portions and the middle is less well impressed (8).

Advantages of the part method:

1. The length of the material is adjusted to the attention span of the learner (8, 24, 30).
2. The learner can see the progress he is making (13).
3. Positive helpful items of transfer (habits and attitudes) developed in the learning of one part carry over to the next in part learning more effectively than in whole learning (18).
4. Attention is renewed at the beginning of each part (8).

Objections to the part method:

1. Successive repetitions of a given part set up between the end of the part and its beginning conflicting associations which inhibit learning (13, 19, 24).
2. There is forgetting of one part while the next is being learned (19, 22).
3. A special act of learning is required to establish the connection between consecutive parts which have been mastered separately (13, 30).
4. The parts learned separately are incompatible when made to function as parts of the whole (16).
5. Temporal and spatial positional establishments acquired in learning by parts do not fit into the whole (18).

6. There is waste of time caused by useless repetition of the known in order to master the unknown. An early part is repeated more often than is necessary in order to make the connection between it and the next later part (24).
7. The rhythm employed on the part is not applicable to the whole (8).

From the above summary it is obvious that there is no clear agreement as to just what are the advantages of or objections to either of the methods of learning and certainly no approach to agreement among present investigators as to which is the superior procedure for any given type of learning material.

Of the investigations mentioned above, the only one which deals with whole and part procedure in trial and error learning and which uses animals as subjects is that of Pechstein (18), and it is this investigation that has suggested the present study. The animals used were white rats and the learning material was the maze. Pechstein's maze was four feet square with a food box eight inches square in the center. It was so constructed that it could be used as one whole maze or as four separate smaller mazes, each leading into the central food box. Each of the four parts was two feet square, contained 7 true alleys and 3 culs de sac and had a distance of 100 inches of true pathway and 36 inches of false pathway. In the entire maze there were 144 inches of false pathway and 400 inches of true. The arrangement of paths was such that there was a high degree of similarity in all the parts and the animal was required in each case to go as far as possible before making a turn and then to turn to the left wherever there was a real choice between paths. That is, he could avoid cul de sac 1 on the principle of going as far as possible before turning, and cul de sac 2 on the principle of turning to the left after having gone as far as possible and having arrived at a junction where a choice between paths had to be made. Culs de sac 3, 4, 6, 7, 8, 9, 10 and 11 could be avoided in the same manner as cul de sac 1; cul de sac 5 in the same manner as cul de sac 2. (Figure 1.)

The animals (rats) used by Pechstein were untrained in actual

maze running. A new group was used for each of the learning methods studied. At the age of eight or nine weeks, in order to accustom the rats to the feeding environment and to being handled, they were taken to the food-box for their regular feeding period of seven minutes each day and were allowed to run over the glass covering of the maze at will. This Pechstein regards as their period of training.

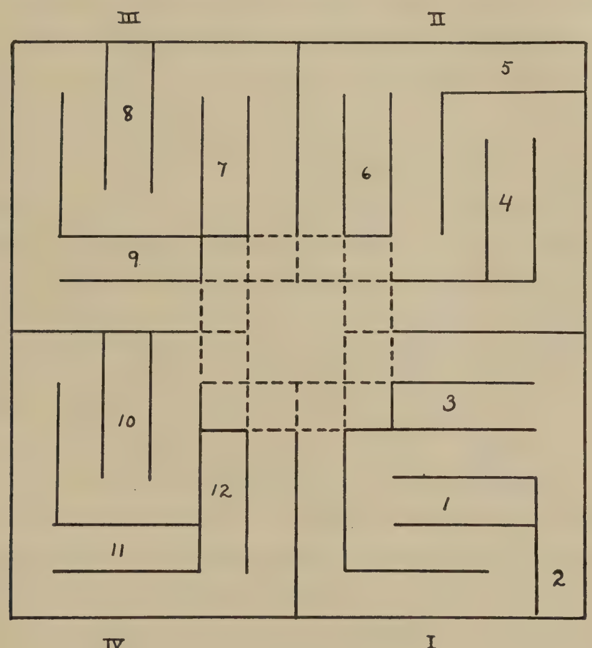

FIG. 1

The experiment was performed in a room electrically lighted, with one light directly above the center of the maze and another six feet from the main entrance of the maze. The experimenter sat behind the main entrance and may or may not have been visible to the rat, depending on the visual acuity of the animal and his position in the maze at any given moment.

Several aspects of Pechstein's experiment make it seem to the writer that it cannot be regarded as conclusive. In the first

place, his maze was so small that the whole of it can scarcely be considered a learning problem sufficiently difficult for adequate testing and comparison of methods, and certainly any one of the parts taken separately cannot be so considered. Moreover, the four sections are so similar in character that they do not in any case constitute four distinct learning problems. In addition to the general item mentioned above characteristic of all parts, namely, that the rat must follow the principle of going as far as possible and turning to the left wherever there is a real choice of paths, there are other specific items of similarity in the various parts of the maze. For instance, the last path in each section, the path which leads into the food-box, is identical in length and character; and, with the exception of section IV, this is true also for the first paths, those leading out of the food-box. In sections I and II the first two of the seven true paths are identical in length and type. In sections III and IV the first three true paths are likewise identical, and in section III the third to the seventh true paths inclusive are like the first to fifth in section IV in regard to distances involved, position and direction of successive turns to be made, and culs de sac to be avoided. Such similarities in the specific character of parts render questionable any conclusion regarding the compatibility of parts functioning in any combination or in the whole. The inequality of illumination in various parts of the maze and the presence of the experimenter within the possible view of the animal while running may or may not have exerted an influence on learning. They are, at best, factors which are uncontrolled and which render results and conclusions less reliable than they would be had the experiment been conducted under fully controlled conditions. Possibly the greatest criticism of Pechstein's experiment is that his rats were in each test untrained and that what he designates as their period of learning was in reality a period of training. What he calls "transfer items"—general maze habit, consciousness of power and favorable emotional tone—which he believes operate at their full value in part procedure but not in whole procedure, are simply variables which can be eliminated through preliminary training of animals before serious experimentation is begun. When these

variables have been eliminated through training, then the experimenter may be sure that the learning is learning of the specific maze pattern involved and of that only. Otherwise the interpretation of the results is of doubtful validity.

Six methods were tested and compared in respect to number of trials, number of errors, and amount of time required to learn to the point that four out of five successive trials were run without error. The methods used were the whole method: Parts I–II–III–IV run in each trial; the pure part method: Part I learned, then II, then III, then IV, and then I–II–III–IV; the progressive part method: Part I, then II, then I–II, then III, then I–II–III, then IV, then I–II–III–IV; the direct repetitive part method: Part I, then I–II, then I–II–III, then I–II–III–IV; the reversed repetitive part method: Part IV, then III–IV, then II–III–IV, then I–II–III–IV; and the elaborative part method: Part I, then II, then III, then IV, then tests on I–III, II–IV, IV–I, III–I, and IV–II. The conclusion reached was that "the complex motor problem is probably always best mastered by one of the several 'modified part' methods. The one universally to be preferred is the 'progressive part' " (18).

II. PROBLEM AND PROCEDURE

A. Statement of purpose

The experiments of all the earlier German and French investigators have been restricted entirely to the study of whole and part procedure in the learning of rote and meaningful material. The subjects have necessarily been human. We are indebted to Pechstein for the one research which has to do with whole and part procedure in trial and error learning with animal subjects, a timely piece of pioneer work in an important field. Pechstein's study has proved to be a very stimulating and suggestive one but, like much pioneer work, is fraught with certain types of imperfections which we have learned to avoid by the use of such improved materials and technique as have been developed during the years since his study was made.

The purpose of this study is, therefore, to repeat the experimental study of Pechstein in whole and part procedure in animal

learning, attempting to improve upon it in the following particulars:

The use of mazes which are more distinct in whole and in parts and which will more readily test the methods of learning employed.

Better control of the objective conditions of the experiment.

The use of trained subjects.

B. Description of apparatus

The apparatus employed was the maze in the University of Michigan psychological laboratories, designated by Cameron (4) as the "Shepard universal type," designed by Dr. J. F. Shepard and briefly described by him (28).

The maze is set up on a platform 15 feet square, reinforced from beneath to prevent warping and sagging and mounted on large casters to permit of its being moved with reference to overhead lighting and other conditions. It is placed in a windowless room built especially for the purpose, located in the ground floor of the building to prevent vibration.

The maze itself is constructed of unit materials, completely interchangeable, permitting an almost unlimited variety of patterns. Wooden posts, $1\frac{3}{4}''$ square and $14''$ high, are set into the floor of the maze in rows, $11\frac{1}{2}''$ apart on centers. Removable posts, similar in cross-section but only $7\frac{1}{2}''$ high are placed as needed midway between the taller ones and in line with them (Figure 2). The four vertical surfaces of all posts are grooved and into these grooves are fitted small panels of five-ply veneer, $7\frac{1}{2}''$ by $4\frac{1}{2}''$, which form the walls of the alleys. Both posts and panels are painted a battleship gray.

The floor of the maze is covered with a black waterproof asphaltic linoleum-like material $\frac{3}{16}''$ thick and laid in sections $11\frac{1}{2}''$ by $11\frac{1}{2}''$ with the corners cut out to fit into the stationary posts.

The entire maze is covered with removable $\frac{1}{2}''$ mesh wire screen cut into $3'$ by $3'$ sections. At intervals of $11\frac{1}{2}''$ holes are cut into the screen which allow the taller posts to slip through them and the screen itself to rest upon the panels and lower posts. The

sections of wire screen are clamped to the taller posts with No. 10 L E B binder clips, which hold them firmly in place.

Each alley of the maze is $5\frac{1}{2}''$ wide ($4''$ between posts). The distance from center to center of posts has been taken in this problem to represent a unit of maze distance. The entire maze, therefore, is 30 units square.

The starting point A in the maze is simply the first unit of the first path and is opened when inserting the animal for a run by

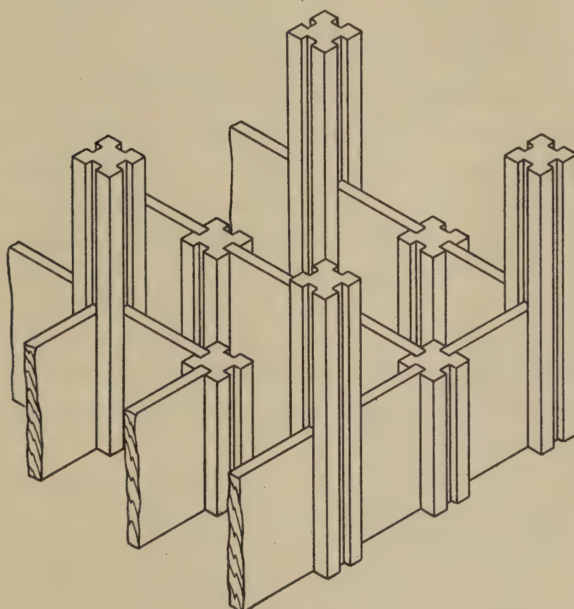

FIG. 2

sliding the panel up. The last true path leads directly into the food-box B. The food-box is $14''$ in height and is formed by placing panels $14''$ by $10\frac{1}{4}''$ between adjacent posts. It contains two compartments. The first and larger compartment, $3'$ by $1'$, is the one into which the animal comes directly from the maze for the nibbles of food which he is allowed between the successive runs. The second smaller one, $1'$ by $1'$, is the one into which he is placed for his regular daily feeding period at the end of his last

run. The second is separated from the first by a panel which may be opened by sliding it up and down in the grooves into which it is fitted.

The entire apparatus is illuminated by 100 flashlight lamps spaced 2 feet o. c. in each direction and suspended 3′ above the maze on a frame made of wire and of wood trusses. Each lamp is covered above and at the sides by a wooden shade 5″ square and 2″ deep. This arrangement of the lamps makes the illumination in all parts of the maze uniform and insures against any variations in lighting conditions which might serve as differential cues to the learner. Above the lighting apparatus is a screen of one thickness of cheese-cloth which serves to protect the maze from any foreign articles or substances which drop down from above.

The ceiling of the maze room is about 15′ above the maze and opens into the room above by means of a 3′ by 3′ aperture. The animal was observed through this aperture while the experiment was in progress; at other times the aperture was closed by means of an iron trap door. The upper room from which the observations were made is a dark room. The illumination used by the observer while taking records was obtained from two 25-watt red lights so shaded that the rays could not fall through the aperture in the direction of the maze.

Five pairs of maze patterns were used,[2] ten mazes in all. They were first charted on graph paper, the details planned to fit the particular learning methods to be tested, and then constructed on the maze platform as designed. Each maze was built in such a way that it could be used as a single whole maze or as four separate smaller mazes or parts, each leading into a food box. For certain learning methods (pure part, progressive part, and direct repetitive part) it was necessary to have two food boxes, into one of which the animal came from Parts I and II and into the other of which the animal came from Parts III and IV. These were located from the point of view of the observer, at the upper and lower left corners of the maze. In each of the four parts of a maze there were 4 sections of true pathway, each containing

[2] Diagrams of all mazes used in this study may be found in the manuscript on deposit in the University of Michigan Library.

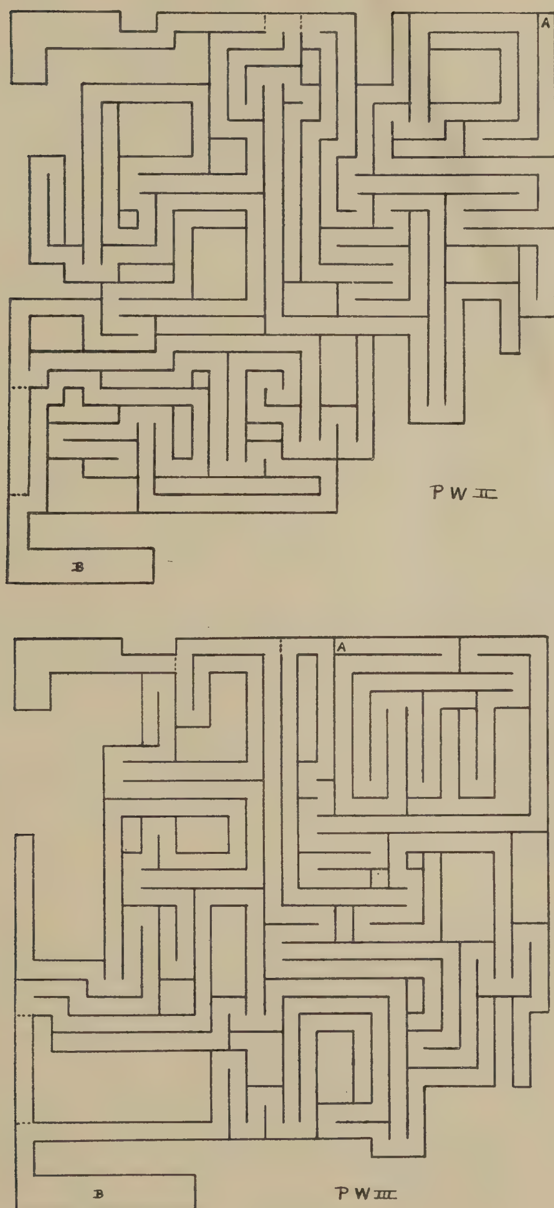

Fig. 3

several alleys, and 3 sections of false pathway, each containing 3 alleys. The first true pathway of Parts II, III, and IV was in each case a continuation of the last true pathway of the preceding part, so that when a maze was used as a whole it contained 13 sections of true pathway of from two to ten alleys each and 12 sections of false pathway of three alleys each. For any one part the amount of true pathway was approximately 100 units and the amount of false pathway approximately 40 units, making a total of approximately 400 units of true and 160 units of false pathway in the whole maze.

There were 12 junctions at which choices between paths had to be made. All junctions were of the same character, requiring the animal to approach through a central alley and to choose between a left and a right turn. The directions of successive turns within any given pathway and the directions of turns at successive junctions were so planned that no rhythm of movement could be set up by the animal which might serve as a cue in making these choices.

Each maze was designed with the idea in mind of avoiding any similarities among the parts of a given maze or among the different mazes in respect to arrangement of pathways, lengths and positions of alleys in corresponding regions, directions of turns, or locations of places of option between alleys, which might affect either positively or negatively the learning of any other maze or part of a maze.

C. The animals used

The animals used were male albino rats, 15 in all. Most of them were bred in the laboratory, a few were secured from a near-by dealer and two from Wistar Institute of Anatomy and Biology in Philadelphia. They were housed in a room adjoining the maze room, in cages of wood and wire, each rat in a cage by himself. They were provided with bedding of wood shavings. Their food consisted of McCollum's diet and well selected table scraps mixed with cod-liver oil. Each rat was allowed a few nibbles of food in the first compartment of the food-box at the end of each run and at the end of his last run for the day was placed

in the smaller compartment of the food-box for the remainder of his daily feeding period. He was allowed to eat as much as he wished unless, as sometimes happened, the character of his work indicated that he was not hungry enough to run consistently, and then the amount was decreased.

All animals had run mazes of comparable difficulty but of different patterns for periods ranging from one to ten months before this experiment was begun. All of them, therefore, were thoroughly accustomed to the maze situation, to human handling and feeding in the food-box. They were "at home" in the situation; it had become a natural one for them, and those variables necessarily present when the animal is placed in an unfamiliar situation—lack of general adaptation, absence of food associations, and emotional disturbance—had been eliminated through the training process.

D. General procedure

After a period of 11 days of practice on a preliminary maze (PW I) planned for the purpose of accustoming the rats to the type of maze to be used and of accustoming the experimenter and recorders to the procedure to be employed, the experiment proper was begun.

Five types of part procedure in learning were compared with the whole procedure. These were designated, borrowing the terms used by Pechstein, as the pure part, the progressive part, the direct repetitive part and the reversed repetitive part methods, the fifth method being a modification of the reversed repetitive part method. In the whole method, each rat ran the entire maze from the starting point A to the food-box B in each trial. In the part methods the order of parts learned was as follows:

Pure part: Part I, then II, then III, then IV, then I–II–III–IV.
Progressive part: Part I, then II, then I–II, then III, then I–II–III, then IV, then I–II–III–IV.
Direct repetitive part: Part I, then I–II, then I–II–III, then I–II–III–IV.
Reversed repetitive part: Part IV, then III–IV, then II–III–IV then I–II–III–IV.

For each part or whole maze the criterion for learning was arbitrarily set at three successive runs without error. In the modified reversed repetitive part method eight trials were given each rat on each of the part combinations and then, regardless of the degree of learning attained, he was set to running the maze as a whole and kept at it until the standard of learning was reached.

The experiment was divided into five parts, the whole procedure being compared in turn with each of the five part procedures employed. Two mazes were used in making each comparison. The rats were separated into two groups called the whole group and the part group. In the first maze of each pair the whole group learned by the whole method, the part goup by a part method; in the second maze of the pair those rats which had previously belonged to the whole group formed the part group, and those which had constituted the part group became the whole group. Thus, in comparing the whole method with any given part method, each rat learned one maze by the whole and one by the part procedure. The purpose of this arrangement was to even out any individual differences which there might be in the learning ability of the rats (and there were clearly such differences) and to even out any differences in the difficulty of learning which might be present due to the differences in character of detail in the various maze patterns (though every effort was made in designing the mazes to make them equal in degree of difficulty).

The experimenter, after placing the dish of food in the first compartment of the food-box, brought the rat from his cage in the adjoining room into the maze room, placed him in the maze at the starting point A and then, until the run was completed, stood or sat in a position beyond possible visibility to the rat. This procedure was repeated until the rat had made his required number of runs. Then he was placed in the smaller compartment of the food-box to finish his meal and the next rat was brought in and run in the same way. During the learning period each rat was kept as nearly as possible equal to all the others in amount of work done until the required standard of learning was reached. A rat learning the whole maze was given 2 runs per evening; one learning a single part or a quarter was given 8 runs; one learning

a combination of 2 parts was given 4 runs; and one learning a combination of 3 parts was given 2 or 3 runs depending on whether his total runs the preceding evening had amounted to one quarter more or less than those of the other rats. When all rats had reached the point where they were running the whole maze, the number of runs for each one was increased to 4, then to 6, then to 8 per evening until he made his three successive correct runs, when it was again dropped to two.

An effort was made to preserve in full the trial and error character of the learning problem and with this object in mind the procedure of preventing returns was omitted. Trial and error learning differs from a mere memory process with either nonsense or meaningful material in the mode of control of the successive events involved. In the latter type of learning the series of primary events is objectively determined; in trial and error learning the order is, within the limits, determined by the learner. In the present investigation there has been no interference on the part of the experimenter with the order of events possible within the maze concerned; the selection has been entirely by the animals themselves.

A record of each run for each rat was kept by a recorder, who lay on a mattress on the floor of the room above and observed the rat through the aperture which connected that room with the maze room below. The recorders were upper class and graduate students selected from among those who were taking the course in comparative psychology. Each recorder was given a period of training before he was permitted to take permanent records for the experiment. He was required to know thoroughly each maze and, by means of a system of symbols which he had learned, to keep for each run of each rat a record which outlined precisely the path taken and indicated where the animal hesitated, stopped or looked into the wrong alley, where he started or entered into the wrong alley and how far, where he played in the pathway, and where he retraced in the true path. Using a stopwatch, the recorder took time on the rat from the moment he entered the last alley of the first pathway until he entered the food-box. This obviously gave a margin of advantage in the item of time to the

rats of the part group as long as they were running a part of the maze. The time spent in the early alleys of the first pathway of each part was not counted as a part of the total learning time, while with the whole group, only the time spent in the early alleys or the first pathway of the maze was omitted. It was necessary, however, to give an advantage in this item to one group or the other owing to the tendency of rats to play in the first few alleys for some seconds before starting to run seriously. During the time that a rat was in the maze absolute silence was observed by both experimenter and recorder.

The question arose as to whether or not, in the learning of any part or part combination by rats of the part groups, the last three perfect runs required as evidence of mastery of that portion of the learning problem should be included in determining the total amount of energy necessary for learning the maze by that procedure. After careful consideration it was decided that they should be included. In the first place, they are an essential part of the method. But a more important consideration is the fact that the repetitions involved do function later in the learning of the whole, even though they may be regarded as over-learning for the immediate part combination concerned. This, of course, raised the question of the relative value of those repetitions in excess of what are necessary for perfect performance (over-learning) for the purpose of relearning later (savings method). The writer knows of no investigation of this question with reference to rats learning a maze. It is, however, a question of memory and there have been some investigations of it as it applies to the human subject learning nonsense syllables. Both Ebbinghaus (7) and Mibai (14) found that all repetitions of nonsense syllables were of equal value; Ebbinghaus found it to be true even of those which were involved in over-learning; and thus far their findings have not been successfully challenged. The results of the present group of experiments have been tabulated and averages computed both with these runs included and with them excluded, and in each case the ultimate advantage has proved to be in favor of the same procedure (Section IV).

The following items regarding each trial of each rat were tabulated:

The number of the trial.
The part or parts of the maze run.
The time required for the run.
The number of errors of each of the following kinds:
  Retracing in the true path.
  Culs de sac taken while going in a forward direction.
  Culs de sac taken while going in a backward direction.
The excess distance travelled
  In the true path.
  In the false path.
The total distance travelled.

Finally the whole procedure was compared with each of the part procedures used in respect to the number of trials required, the amount of time taken, the number of errors made, the units of excess distance travelled, and the units of total distance travelled until the learning was complete, that is, until each of the animals had made three successive runs through the entire maze without error.

It is fully recognized that these criteria are not of equal value in determining the relative effectiveness of the various procedures tested. The one regarded as most significant in this problem is that of the total distance travelled. This criterion includes both the number of trials and the units of excess distance travelled in each trial and is, more than any other single criterion or combination of criteria, a true measure of the amount of energy spent in learning.

III. RESULTS OF EXPERIMENTS

A. Comparison of whole with pure part procedure

One pair of mazes and 8 rats were used to compare the relative effectiveness of the whole and pure part procedures in learning. The first maze, PW II, contained 349 units of true pathway and 150 units of false pathway; the second, PW III, contained 388 units of true and 153 units of false pathway. In learning the

first maze the rats numbered 60, 68, 69, and 70 constituted the "whole" group and those numbered 54, 64, 66, and 71 constituted the "part" group. In learning the second maze the groups were reversed.

For each maze the procedure was as follows: each rat of the "part" group was run in Part I of the maze 8 times per evening until three successive correct runs had been made. Then he was transferred to Part II until the same standard of success had been attained, likewise in turn to Part III and Part IV. When all four parts had been learned, the rat was run on the whole maze two times per evening. Each of the rats of the "whole" group ran the entire maze two times per evening until all the rats of the part group were ready to be put upon the whole. Then the number of runs was increased for all rats that had not yet completed the learning. Eleven evenings were spent on each of the two mazes. The general procedure employed was that described in Section II D.

The learning of the parts singly by the part group and of the whole maze by the whole group proceeded in the way usual with trained rats. The rats started out promptly and, after the first few alleys were passed, ran rapidly until the food-box was reached, though with hesitations at junctions and with frequent errors in choice of paths. Hesitations and errors were gradually eliminated and finally the three consecutive correct runs were completed.

When the rats of the part group were transferred from Part IV to the whole, their behavior was different. They stopped at the transitions between parts, often for many seconds, nosing and pawing at the panel blocking the opening which had previously led into the food-box. Sometimes, after this period of futile effort to get through, they retraced into the preceding section, but more often they went on into the next section of the maze and repeated this behavior at the next point of transition. But there was little evidence of recognition of any of the parts as having been learned before. The first few runs on the whole were in character very much like the first runs of the same rats on any new maze except for the hesitations at transition points.

In studying the pure part procedure it is of interest to compare the effort expended upon learning the parts separately with that expended upon the act of combining the parts into the whole. Using as criteria the amount of time, the number of trials, the number of errors and the number of units of total distance travelled, the results show that the amount of energy required was greater in terms of time, trials and total distance, but less in terms of errors, for combining the parts after they had been learned singly than for learning them singly originally. The percentages obtained are as follows:

	PW II		PW III		PW II AND III	
	Parts singly	Parts combined	Parts singly	Parts combined	Parts singly	Parts combined
Time	37.8%	62.2%	36.9%	63.1%	37.35%	62.65%
Trials	35.0	65.0	31.5	68.5	33.25	66.75
Distance	39.2	60.8	33.7	66.3	36.21	63.79
Errors	57.1	42.9	53.9	46.1	55.50	44.50

In only one respect, then, did the act of connecting the parts already learned appear to be less difficult than the act of learning them separately, in respect to number of errors made. An examination of the units of excess distance represented by these errors reveals that in PW III there were even more units of excess distance taken in the process of combining the parts into the whole than in the act of learning them singly, though the difference was very slight (.1%). It is evident that in learning by the pure part method approximately two-thirds of the energy of the learners was spent upon the task of combining into a whole the parts which had already been learned singly. Notwithstanding the fact that more energy was required to combine the parts than had been required to learn them singly, it is clear that some learning was retained from having run the parts separately, for the amount in time, errors, trials and total distance was in general less for the parts groups in running the whole maze than for the whole groups.

Table I gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of

TABLE I

		PW II		PW III	
Group of rats		Part	Whole	Part	Whole
Number of trials	Parts	$\frac{37.25}{4}$		$\frac{40}{4}$	
	Whole	17.25		21.7	
	Both	26.56	22.2	31.7	20.5
Time	P	15′ 48.27″		20′ 17.0″	
	W	26′ 49.92″		34′ 35.4″	
	B	42′ 38.19″	40′ 13.3″	54′ 52.4″	38′ 6.5″
Number of errors:					
Retracing in true path	P	8.75		6.0	
	W	2.75		7.0	
	B	11.50	5.7	13.0	6.0
Blind forward	P	37.50		30.5	
	W	33.30		22.5	
	B	70.80	59.2	53.0	39.0
Blind backward	P	3.75		2.2	
	W	1.50		3.5	
	B	5.25	2.0	5.7	3.5
All kinds	P	50.00		38.7	
	W	37.50		33.0	
	B	87.50	67.0	71.7	48.5
Number of units of excess distance:					
In true path	P	352.0		209.5	
	W	160.5		338.5	
	B	512.5	200.0	548.0	292.0
In false path	P	783.7		646.5	
	W	605.5		520.7	
	B	1389.2	1182.7	1167.2	821.7
Total	P	1135.7		856.0	
	W	766.0		859.2	
	B	1901.7	1382.7	1715.2	1113.7
Number of units of total distance traveled	P	4384.89		4736.0	
	W	6786.25		9278.8	
	B	11171.14	9130.5	14014.8	9067.75
Rats used		54, 64, 66, 71	60, 68, 69, 70	60, 68, 69, 70	54, 64, 66, 71

errors of each type, number of units of excess distance taken in the true pathway and in the false pathway, and number of units of total distance travelled. In order to make the number of trials for learning required by the part group comparable to that required by the whole group, the trials of the part group were reduced to whole equivalents. This was done by dividing by 4 the total number of trials spent on parts and adding to that quotient the number of trials spent in combining the parts into the whole. Errors were classified into three types—retracing in the true path, culs de sac taken while running in the forward direction, and culs de sac taken while running in the backward direction in the maze. Starts and actual entrances into culs de sac were counted as errors of the second and third types, depending on the direction in which the animal was running at the time. The number of units of total distance travelled was computed by the formula: numbers of trials $\times$ length of true pathway $+$ excess distance travelled.

Examination of these data shows that in every particular the whole groups were superior to the part groups in learning the mazes. With a few exceptions in a few items this was true for individuals as well as for groups. Comparing for individuals the energy spent in learning one maze by the whole method with that spent in learning the other maze by the part method, in the results obtained from three rats there were differences in favor of the part method in some of the items: Rat 64 took more trials by one and more units of total distance in learning PW III by the whole method than in learning PW II by the pure part method; Rat 60 made more errors of the blind-forward type and took more units of distance in the false pathway in learning PW II by the whole method than in learning PW III by the pure part method; Rat 68 took more time, more errors of the blind forward type, more total errors, and more units of excess distance in the false pathway in learning PW II by the whole method than in learning PW III by the pure part method. None of these differences in favor of the pure part procedure were large, however, and all of them were greatly overbalanced by the many times larger number of items showing a contrary result, even with

these three rats, and by the amount of the differences in favor of the whole procedure for all other rats.

Table II gives the average differences in favor of the whole procedure for each of the mazes separately and for both combined in absolute amounts and in percentages. It will be seen that by whatever criterion the two methods are compared there was an advantage for the whole—25.8% in number of trials, 18.0% in amount of time, 27.8% in number of errors, 31.1% in number of units of excess distance, and what is most important of all, 26.7% in number of units of total distance travelled.

TABLE II

	PW II		PW III		PW II AND III	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	4.36	16.4	11.2	35.3	7.78	25.8
Time	2′ 24.89″	5.6	16′ 46.00″	30.5	9′35.44″	18.0
Errors:						
Retracing in true path	5.8	50.4	7.0	53.8	6.4	52.1
Blind forward	11.6	14.9	14.0	26.4	12.8	20.6
Blind backward	3.25	61.9	2.2	38.6	2.72	50.2
All kinds	20.6	23.4	23.2	32.3	21.9	27.8
Excess distance:						
In true path	312.5	61.1	256.0	46.9	284.2	54.0
In false path	206.5	14.8	345.5	29.6	276.0	22.2
Both	519.0	27.2	601.5	35.0	560.2	31.1
Total distance	2040.64	18.2	4947.1	35.2	3493.87	26.7

Attention has been called to the fact that each maze pattern was designed with the idea in mind of avoiding similarities among parts of the same maze as well as among mazes; that is, each part was unique, so that there were no details of one pattern which might carry over either to facilitate or to interfere with the learning of the next. Moreover, the animals used were thoroughly trained and this was done for the purpose of reducing the variables to one only, that of the specific maze pattern involved. It is interesting to note that with these factors under control,

there was no evidence of increasing readiness on the part of the rats to attack successive new mazes and no consistently increasing facility exhibited in the learning of the new mazes. The order of difficulty, from least to greatest, in learning the four parts of the maze PW II when measured by average amount either in trials, time, errors or total distance was II, I, III, IV. For PW III, when measured by average amount in trials, time or total distance, the order was II, IV, I, III; when measured by average number of errors it was IV, II, I, III. There were variations from this order for individual rats on each maze, but in no instance was the order either I, II, III, IV or IV, III, II, I in any item. In other words, there is no evidence that the learning of one part either aided or hindered the learning of any later part in respect to the time or energy required; each part appears rather to have constituted a distinct unique learning problem in itself unaffected by any other part.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the pure part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to total distance travelled, which is the truest measure of energy expended, the advantage for the whole procedure was 26.7%.
2. That in the pure part procedure learning the parts constituted approximately $\frac{1}{3}$ and learning to combine the parts into the whole approximately $\frac{2}{3}$ of the learning activity.
3. That, when all criteria are taken together, learning the parts singly first did appear to reduce somewhat the amount of energy required to master the whole later, though there were many exceptions in different items for individual animals.
4. That, when all factors are adequately controlled, the learning of one part or of one maze did not affect either positively or negatively the learning of later mazes.

B. Comparison of whole with reversed repetitive part procedure

One pair of mazes and ten rats were used in testing the relative effectiveness of the whole and reversed repetitive part procedures

in learning. The first maze of the pair, PW IV, contained 394 units of true and 152 units of false pathway; the second, PW V, contained 413 units of true and 157 units of false pathway. In learning PW IV the rats numbered 60, 62, 68, 69, and 70 constituted the whole group and those numbered 54, 64, 66, 71 and 73 constituted the part group. In learning PW V the groups were reversed.

For each maze the procedure was as follows: each rat of the part group ran Part IV of the maze 8 times per evening until three successive correct runs had been made. Then Part III was added and the rat was required to run Parts III and IV together 4 times per evening until the same degree of mastery had been attained. Likewise in turn he was transferred to Parts II–III–IV together running these sections 3 or 2 times per evening; and finally to the whole running it 2 times per evening. With each transfer he ran first a new section of the maze and then one or more already learned sections, a procedure requiring not ony the mastery of the new, but along with it, a review of the old in each case. Each of the rats of the whole group ran the entire maze two times per evening until all the rats of the part group had been transferred to the whole. Then the number of runs was increased for all rats which had not yet completed the learning. Nineteen evenings were spent on the maze PW IV and eighteen evenings on PW V. The general procedure was that described in Section II D.

The behavior of the rats of the part groups in learning Part IV and those of the whole group in learning the mazes as a whole proceeded in the way described above for similar learning in mazes PW II and PW III. When the rats of the part groups were transferred from Part IV to Parts III–IV, they attacked the new learning problem with the usual eagerness and with the usual hesitations and errors in choice at junctions. Upon reaching the point of transition from Part III to Part IV, at first most of the rats hesitated before proceeding into Part IV, but these hesitations at the points of transition were generaly dropped after a few runs. In no instance did the animal in his first trial after being transferred to a new part run the already learned and sup-

posedly familiar section as if he recognized it. Of the total of 30 times that rats were transferred from one part (IV, III–IV, or II–III–IV) to the preceding one there was just once that the run through the already learned section of the maze was without error, and even in that instance it was not free from hesitation. After the transfer to the whole, when each rat had had the maximum of review of the already learned sections, the first run of all rats excepting one (Rat 71) were in character very much like the first runs of the same rats on any new maze. From 1 to 9 trials were required before any of the other rats made a run from the beginning free from error in the already learned parts, the average for the two mazes being 3 trials. Most of these errors were made in the part learned latest and the rats often showed evidence of recognizing earlier learned portions of the maze before reaching the food-box. That there was some learning retained from having learned the last three sections by this reversed cumulative method, however, is indicated by the fact that the amount in trials, time, errors and total distance is in general very much less for the rats of the part group after they were set to running the maze as a whole than for the rats of the whole group.

Table III gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true pathway and in the false pathway, and number of units of total distance travelled. Errors were classified and counted and number of units of total distance computed as before. Examination of these data shows that in every particular (except excess distance in true pathway in PW IV) the whole groups were superior to the part groups in learning the mazes. With very few exceptions this was true for individuals as well as for groups. In the results obtained from two rats there were differences in favor of the part method in a few of the items: Rat 62 took more trials, more time and more errors of the blind-forward type in learning PW IV by the whole method than in learning PW V by the reversed repetitive part method; Rat 69 made more errors by 1 of the blind-backward type in learning PW IV by the whole method

TABLE III

		PW IV		PW V	
Group of rats		Part	Whole	Part	Whole
Number of trials	Parts	143/4		103.75/4	
	Whole	14		14.8	
	Both	49.75	33.6	40.7	18.0
Time	P	1 hr. 2′ 39.47″		57′ 26.66″	
	W	24′ 54.38″		30′ 31.14″	
	B	1 hr. 27′ 33.85″	1 hr. 12′ 11.3″	1 hr. 27′ 57.80″	30′ 13.52″
Number of errors:					
Retracing in true path	P	12.2		11.4	
	W	7.2		7.8	
	B	19.4	16.6	19.2	5.0
Blind forward	P	65.4		48.6	
	W	21.6		24.4	
	B	87.0	50.75	73.0	42.8
Blind backward	P	2.0		4.8	
	W	3.0		3.0	
	B	5.0	4.0	7.8	2.0
All kinds	P	79.6		64.8	
	W	31.8		35.2	
	B	111.4	71.35	100.0	49.8

Number of units of excess distance:					
In true path	P	546.0		1093.6	
	W	413.4		905.2	
	B	959.4	1006.2	1998.8	266.0
In false path	P	1380.0		1234.6	
	W	447.6		542.4	
	B	1827.6	1133.6	1777.0	981.2
Total	P	1926.0		2328.2	
	W	861.0		1447.6	
	B	2787.0	2139.8	3775.8	1247.2
Number of units of total distance traveled	P	16011.5		13040.4	
	W	6377.0		7560.0	
	B	22388.5	15378.2	20600.4	8681.2
Rats used		54, 64, 66, 71, 73	60, 62, 68, 69, 70	60, 62, 68, 69, 70	54, 64, 66, 71, 73

than in learning PW V by the reversed repetitive part method. The number of units of excess distance due to retracing in the true path was so great for these two rats, which happened to be in the same group, that in one of the mazes (PW IV) the average for their group (whole group) in this item was somewhat greater than for the other group. These differences, however, excepting in the number of trials required by Rat 62 for learning, were so small that they are insignificant. In general, the differences in favor of learning by the whole method were considerably greater when the whole method was compared with the reversed repetitive part method than when it was compared with the pure part method.

Again it is of interest to note the relative amount of learning effort devoted to the parts and to the whole in this part procedure. It is, of course, impossible to determine just what proportion was expended on learning each part separately or just what porportion was expended on combining the parts already learned, but it is possible to determine the proportion given to the learning of Parts II, III and IV and that required to complete the learning by adding Part I. The results obtained from the two mazes show that for all of the part combinations taken together, for each of them separately, and for the learning of the whole by the addition of Part I, the proportions expressed in terms of the criteria we have been using were

	PART IV	PART III–IV	PART II–III–IV	PART COMBINATIONS	WHOLE
Trials	5.2%	19.8%	43.0%	68.0%	32.0%
Time	5.7	21.8	41.0	68.5	31.5
Errors	7.2	24.3	36.8	68.3	31.7
Excess distance	6.4	23.0	35.4	64.8	35.2
Total distance	5.4	20.6	42.0	68.0	32.0

As these percentages indicate, all of the criteria employed give fairly consistent results in the measurement of the amount of energy expended by the rats of the part groups in each of the learning acts involved. It will be observed that to learn the part combinations became increasingly difficult through the first three

learning acts (IV, III–IV, and II–III–IV). This was true, not only for groups, but also for individual rats with the exception of Rats 66 and 71 which had proportionally more difficulty in combining Parts III and IV than in combining Parts II, III and IV. Up to the point where Parts II, III and IV had been successfully combined, the proportion of energy expended by the rats of the part groups was approximately only $\frac{2}{3}$ of the total amount of energy required for complete learning, though it had already exceeded that required for learning by those of the whole groups. It is not easy to explain just why the problem for the rats of the part groups increased in difficulty as part combinations became more complex through three learning acts and then proved to be less difficult in the fourth and most complex combination of all. It may have been due to the excessive number of repetitions given the II–III–IV combination before it was mastered which resulted in fixing the series of reactions so securely that they were retained better than the preceding series had been. Or it may be due (and this is more probable) to the fact that when the rats of the part group were ready to run the maze as a whole the number of trials per evening was increased gradually from two to six. That is, the decrease in amount of energy necessary to reach the standard of three successive correct performances may have been a function of the massing of repetitions. It raises again the question of the relative value of distributed and massed repetitions in their influence on immediate recall, a question which the writer proposes to investigate experimentally in the near future.

Table IV gives the average differences in favor of the whole procedure for each of the mazes separately and for the two mazes combined, both in absolute amounts and in percentages. It will be observed that on one maze (PW IV) in one item, that of excess distance in the true path, the advantage appeared to be with the part method of learning. This is due to the fact that two rats (Rats 62 and 69, more particularly 62) which were in the whole group retraced excessively in learning this maze. Rat 69 was under all circumstances a poor learner. Rat 62 had, in a previous problem, been required to set up a habit in choice between paths

when coming out of a false alley which, when carried over into this problem, led him to retrace in the true path. When his record is excluded, the advantage for the whole procedure was without exception in any item and was greater in all items. Including the records of these two rats, the superiority of the whole procedure over the reversed repetitive part procedure in this test in terms of the criteria used was 44.1% in number of trials, 41.5% in amount of time, 43.1% in number of errors, 45.0% in number of units of excess distance travelled, and 44.5% in number of

TABLE IV

	PW IV		PW V		PW IV and V	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	16.15	32.4	22.7	55.7	19.42	44.1
Time	15′ 22.55″	17.5	57′ 44.28″	65.6	36′ 33.41″	41.5
Errors:						
Retracing in true path	2.8	14.4	14.2	73.9	8.5	44.1
Blind forward	36.25	41.6	30.2	41.3	33.22	41.4
Blind backward	1.0	20.0	5.8	74.3	3.4	47.1
All kinds	40.0	36.0	50.4	50.2	45.2	43.1
Excess distance:						
In true path	−46.8	−4.8	1732.8	86.7	843.0	40.9
In false path	694.0	38.0	795.8	44.7	744.9	41.3
Both	647.2	23.2	2528.6	66.9	1587.9	45.0
Total distance	7010.3	31.3	11919.2	57.8	9464.7	44.5

units of total distance travelled. Excepting in number of errors made, the advantage for the whole compared with the reversed repetitive part method was considerably greater than the advantage for the whole compared with the pure part method.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the reversed repetitive part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to number of units of total

distance travelled, which is the truest measure of energy expended, the advantage for the whole procedure was 44.5%.

2. That the advantage in favor of the whole procedure was greater when the whole procedure was compared with the reversed repetitive part procedure than when it was compared with the pure part procedure.
3. That in the reversed repetitive part procedure, learning three of the four parts of the maze constituted approximately $\frac{2}{3}$ and completing the learning by the addition of the fourth part approximately $\frac{1}{3}$ of the learning activity.
4. That, when all criteria are taken together, learning Parts II–III–IV in combination by the reversed repetitive part method did reduce somewhat the amount of energy required to master the whole by adding Part I, though there are many exceptions in different items both for the groups and for individual animals.
5. That in nearly every item and particularly in the number of units of total distance travelled, the amount of energy expended by the part groups of rats on learning three of the four parts of a maze exceeded that expended by the whole groups on learning the maze as a whole.
6. That the fact that less energy was required to add I to II–III–IV than was required to add II to III–IV may be a function of the distribution of repetitions, but this is in need of further investigation.

C. Comparison of whole with modified reversed repetitive part method

One pair of mazes and ten rats were used in testing the relative effectiveness of the whole and the modified reversed repetitive part procedures in learning. The first maze of the pair, PW VI, contained 351 units of true and 147 units of false pathway; the second, PW VII, contained 355 units of true and 155 units of false pathway. In learning Maze PW VI the rats numbered 60, 66, 68, 70 and 74 constituted the whole group, and those numbered 54, 64, 69, 73 and 76 constituted the part group. In learning Maze PW VII the groups were reversed.

The procedure differed from that employed in the reversed repetitive part method only in respect to the number of runs given to each of the part combinations for the rats of the parts groups. In the reversed repetitive part method the animals were required to master each part combination before being put to running the next; in this modified reversed repetitive part method they were given eight trials apiece on each of the part combinations (IV, III–IV, II–III–IV) and then, regardless of the amount of learning acquired, were set to running the maze as whole. One evening was devoted to each of the part combinations. The rats of the whole groups ran the whole maze in each trial, as usual, and were given 2 trials the first evening, 4 the second, and 6 the third. Then all rats were given 6 runs per evening until learning was complete. Ten evenings were spent on Maze PW VI and nine evenings on Maze PW VII.

The behavior of the rats of the part groups in learning Part IV and of the whole groups in learning the whole maze was similar to their behavior in learning the corresponding portions of Mazes PW IV and PW V. In the eight runs given each rat of the part groups on each part combination, five rats (Rats 54, 64, 60, 68 and 70) succeeded in making three successive correct runs on Part IV, three rats (Rats 54, 69 and 70) on Parts III–IV, and none on Parts II–III–IV. That is, according to the standard adopted, they mastered those parts. With every transfer from one part combination to another the new learning problem was attacked eagerly. Upon reaching the point of transition between the new and the old, however, there was much less tendency to hesitation than there had been in the preceding pair of mazes. On the contrary, in most of the runs the animals made that turn at the transition point just as they made any other turn in the maze, but they did not then run the already-practiced portion of the maze as if it were familiar. In six of the thirty times the transfer was made from practiced to unpracticed parts the runs were without error in the practiced portions (Rats 54, 64 and 73 from Part IV to III–IV, Rat 69 from Part III–IV to II–III–IV, and Rat 64 from Part II–III–IV to the whole), but in only one instance (Rat 64 on the whole) was this accuracy consistently maintained

TABLE V

		PW VI		PW VII	
Group of rats		Part	Whole	Part	Whole
Number of trials	Parts	48/4		48/4	
	Whole	19.6		14.6	
	Both	31.6	34	26.6	18.2
Time	P	20′ 50.74″		19′ 35.56″	
	W	30′ 34.56″		20′ 16.80″	
	B	51′ 25.30″	46′ 35.36″	39′ 52.36″	31′ 58.66″
Number of errors:					
Retracing in true path	P	4.8		2.8	
	W	5.6		3.0	
	B	10.4	6.4	5.8	8.2
Blind forward	P	27.4		32.4	
	W	33.8		19.6	
	B	61.2	52.2	52.0	36.8
Blind backward	P	1.4		1.4	
	W	1.0		1.0	
	B	2.4	3.0	2.4	2.2
All kinds	P	33.6		36.6	
	W	40.4		23.6	
	B	74.0	61.6	60.2	47.2
Number of units of excess distance:					
In true path	P	347.0		127.2	
	W	323.6		71.2	
	B	670.6	189.6	198.4	393.0
In false path	P	567.6		728.0	
	W	693.2		327.2	
	B	1260.8	1003.2	1055.2	857.6
Total	P	914.6		855.2	
	W	1016.8		398.4	
	B	1931.4	1192.8	1253.6	1250.6
Number of units of total distance traveled	P	5126.6		5115.2	
	W	7896.4		5581.5	
	B	13023.0	13126.8	10696.7	7711.6
Rats used		54, 64, 69, 73, 76	60, 66, 68, 70, 74	60, 66, 68, 70, 74	54, 64, 69, 73, 76

through more than two runs. The errors, though, were neither numerous nor serious in character and were quickly dropped. The fact that the amount in trials, time, errors, and total distance, excepting for one item in one maze (excess distance in the true path in PW VI), was considerably less for the rats of the part group after they were set to running the maze as a whole than for the rats of the whole group indicates that the practice on the part combinations contributed in some measure to the learning of the mazes.

Table V gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance in the true pathway and in the false pathway, and number of units of total distance travelled. Examination of these data shows that in general the whole groups were superior to the part groups in learning the mazes, but with exceptions in the number of trials and the number of errors of the blind-backward type in Maze PW VI and in the number of errors of the retracing type and the number of units of excess distance travelled in the true path in Maze PW VII. In particular items this superiority in learning by the whole method was true for individual animals, too, though with a great many exceptions. In the results obtained from eight rats there were differences in favor of the part method in some of the items.

Rat 54 in errors of the blind-backward type.

Rat 60 in trials, time, errors of each type, total errors, excess distance in the true path, and total distance travelled.

Rat 68 in trials, time, errors of the retracing and blind-forward types, total errors, excess distance in the true path, and total excess distance.

Rat 69 in trials, time, errors of the blind-backward type, and total errors.

Rat 70 in trials, time, errors of each type, total errors, excess distance in the true and in the false pathway, and total excess distance.

Rat 73 in errors of the blind-backward type.

Rat 74 in excess distance in the true and in the false pathway, total excess distance, and total distance travelled.
Rat 76 in errors of the blind-backward type.

Rats 68 and 70, two of the best learners under normal conditions, were ill a part of the time while learning Maze PW VI by the whole procedure and so were not at their best. This may account in some measure for the number of items in which the part method appeared to have been better for them than the whole method, but when we apply the criterion which is the best

TABLE VI

	PW VI		PW VII		PW VI AND VII	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	−2.4	−7.5	8.4	31.6	3.0	12.05
Time	4′ 49.9″	9.3	7′ 53.7″	19.8	6′ 21.8″	14.5
Errors:						
Retracing in true path	4.0	38.4	−2.4	−41.3	.8	−1.45
Blind forward	9.0	14.7	15.2	29.2	12.1	21.9
Blind backward	−.6	−25.0	.2	8.3	−.2	−8.35
All kinds	12.4	16.7	13.0	21.5	12.7	19.1
Excess distance:						
In true path	481.0	71.7	−194.6	−98.0	143.2	−13.15
In false path	257.6	20.4	197.6	18.7	227.6	19.55
Both	738.6	38.2	3.0	.23	370.8	19.21
Total distance	−103.8	−0.7	2985.1	27.9	1440.7	13.6

measure of energy required for learning, namely, the total distance travelled, the whole procedure was the superior one for them. This was not true for Rats 60 and 74. The part method employed proved to be better for them in respect to total distance travelled. Though the exceptions for the mazes taken separately and for the animals taken separately were numerous, when averages are computed for both mazes and for all rats, the advantage of the whole over the part procedure is obvious. Table VI gives the average differences in favor of the whole method for each of the mazes separately and for the two mazes combined both in abso-

lute amounts and in percentages. It will be observed that for some items the part procedure had the advantage—for errors of the retracing type and for number of units of excess distance in the true path in PW VII, for errors of the blind-backward type in the Maze PW VI, and for all three items in the average of the two mazes taken together. When all kinds of errors are totalled and excess distance in both the true and the false pathway are considered the advantage was still with the whole procedure. Expressed in terms of the criteria employed the superiority of the whole over the modified reversed repetitive part method was 12.05% in number of trials, 14.5% in amount of time, 19.1% in number of errors, 19.21% in number of units of excess distance travelled, and 13.6% in number of units of total distance travelled.

It is again of interest to note the relative amount of learning effort given to the learning of the parts and to learning the whole by the part groups. The results obtained from the mazes show that for all of the part combinations taken together, for each of them separately, and for the learning of the whole by the addition of Part I, the proportions were:

	IV	III–IV	II–III–IV	PARTS	WHOLE
Trials	6.9%	13.7%	20.6%	41.2%	58.8%
Time	6.7	15.6	21.8	44.1	55.9
Errors	8.3	20.0	23.0	51.3	48.7
Excess distance	7.1	25.3	23.2	55.6	44.4
Total distance	7.2	15.3	20.8	43.3	56.7

With this method, up to the point where Part II, III, and IV were combined, the proportion of energy expended by the rats of the part groups was approximately $\frac{1}{2}$ of the total amount of energy required for complete learning.

Compared with the reversed repetitive part procedure the modified reversed repetitive part procedure showed certain very marked differences. In learning by the latter method more animals were able to run from a new into an already practiced section of the maze without making errors in the first runs in the

latter section. The errors made under these conditions were less serious in character and were more quickly dropped. The whole groups showed less superiority in the items in which they were superior at all, and more items in which they were not superior to the part groups. The relative amount of learning effort given by the part groups to the parts was less and that given to the whole was more. There was less consistency in results for the mazes taken singly, for the animals taken singly, and for the mazes taken together, and for the animals taken by groups. The absolute amounts and percentages of advantage in the various items were less for the whole group. In other words, in all particulars the modified reversed repetitive part method more closely approached the whole method in effectiveness for learning than did the reversed repetitive part method.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the modified reversed repetitive part procedure in this study we find—

1. That the whole procedure was superior, whatever be the criterion applied. In respect to the number of units of total distance travelled the advantage for the whole procedure was 13.6%.
2. That the advantage in favor of the whole procedure was less when the whole procedure was compared with the modified reversed repetitive part method than when it was compared with either the reversed repetitive part method or the pure part method.
3. That in the modified reversed repetitive part procedure, practice amounting to 8 trials on each of the part combinations (IV, III–IV, II–III–IV) of the maze constituted approximately $\frac{1}{2}$ and completing the learning by the addition of the fourth part (Part I) approximately $\frac{1}{2}$ of the learning activity.
4. That practice amounting to 8 trials on each of the part combinations reduced the amount of energy required to master the whole by the addition of Part I. There was only one exception (number of units of excess distance in the true path in Maze PW VI).

5. That the modified reversed repetitive part method compared more favorably with the whole method in effectiveness in learning than either the reversed repetitive part method or the pure part method.

D. Comparison of whole with progressive part procedure

One pair of mazes and ten rats were used to test the relative effectiveness of the whole and the progressive part procedures in learning. The first maze of the pair, PW VIII, contained 404 units of true and 152 units of false pathway; the second, PW IX, contained 395 units of true and 150 units of false pathway. In learning Maze PW VIII the rats numbered 60, 66, 68, 70, and 74 constituted the whole group and those numbered 54, 64, 73, 75, and 76 constituted the part group. In learning Maze PW IX the groups were reversed.

For each maze the procedure was as follows: each rat of the part group was run in Part I of the maze 8 times per evening until three successive correct runs had been made. Then he was transferred to Part II and run on that part 8 times per evening until the same standard of success had been attained. Then he was required to run parts I and II together 4 times per evening until he had made three consecutive correct runs. This was followed by running Part III 8 times per evening until it was learned, then adding it to the I–II combination and running this combination three times per evening (two times every third evening) until it was learned. Likewise Part IV was learned and added to the I–II–III combination and two trials were given on the whole each evening until all the rats were ready to run the whole. Then six trials were given each evening until the maze was mastered. For the rats of the part groups this procedure necessitated the mastery of six separate part combinations (I, II, I–II, III, I–II–III, and IV) before the maze was finally mastered as a whole. It resembles the pure part method in that each part of the maze was learned separately, but differs from the pure part method in the fact that each part, after it had been learned, immediately became a functional part of a larger combination which grew progressively more complex as the parts were added to it. This

method resembles the reversed repetitive part method in that the learning problem grew progressively more complex, but differs from it in that the learning of the new and the review of the already-learned parts of the maze were not combined in the same learning act, that the learning material of the final learning act included only that which had already been learned, and that the maze was learned from beginning to end rather than from end to beginning. Each of the rats of the whole group ran the entire maze two times per evening. On Maze PW VIII the number of trials was increased to six per evening when all of the rats of the part group were ready to be put upon the whole, but this was not possible on Maze PW IX because all excepting one of the rats of the whole group had mastered the maze before some in the part group had completed the learning of the part combinations. Eighteen evenings were spent on Maze PW VIII and twenty-five on Maze PW IX. The general procedure was that previously described (Section II D).

The learning of the parts singly by the rats of the part groups and of the whole maze by the rats of the whole groups proceeded in the way described for similar learning on previous mazes. When the rats of the part groups were transferred from single parts to combinations formed of single parts already learned, that is, from Part II to I–II, from III to I–II–III, and from IV to the whole, their behavior was different. Just as in learning Mazes PW II and PW III by the pure part procedure, they stopped at the transitions between parts, often for many seconds, trying to find their way through the old path into the food-box. Sometimes they retraced from the point of transition, though more often they proceeded into the next section of the maze. But in all cases there was little evidence of recognition of the path as a familiar one. In no instance was the first run after transference from a learned part to a combination of learned parts free from hesitations, in only three out of the thirty instances was it free from actual error, and none of these errorless first runs was followed immediately by a second run without error. The number of errors in these runs varied from 0 to 6, the average for all rats on both mazes being 2. Except for hesitations at

transition points, and a greater amount of retracing, the first few runs on combinations of already-learned parts for most rats were in character very much like the first runs of the same rats on any new maze. Using the criteria of amount of time, number of trials, number of errors, number of units of excess distance travelled, and number of units of total distance travelled, a comparison of the amount of effort expended upon the different acts shows that learning to combine the already-mastered parts required from 2 to 4 times as much energy as learning the parts singly. The amounts varied according to the criterion employed. The percentages obtained were:

	I	II	I–II	III	I–II–III	IV	PARTS	WHOLE
Trials	3.5%	5.3%	10.9%	5.6%	32.6%	4.9%	62.8%	37.2%
Time	4.2	5.1	10.2	6.3	32.3	4.8	62.9	37.1
Errors	7.1	10.8	9.2	9.9	27.7	7.6	72.3	27.7
Excess distance	7.0	9.6	9.3	10.9	25.9	8.5	71.2	28.8
Total distance	4.4	5.5	10.5	6.1	32.1	5.5	64.1	35.9

When the proportions of energy spent on learning the parts separately and on learning the parts combined are computed, the results show that considerably more than $\frac{2}{3}$ of the total energy required for learning was devoted to the act of combining already-learned sections and less than $\frac{1}{3}$ to the original mastery of the parts themselves. The actual percentages were

	PARTS SINGLY	PARTS COMBINED
Trials	19.3%	80.7%
Time	20.4	79.6
Errors	35.4	64.6
Excess distance	36.0	64.0
Total distance	21.5	78.5

That some learning was acquired and retained as a result of learning the parts separately and combining them progressively is evident from the fact that the amount in time, errors, trials, excess distance and total distance was in general less for the part groups in running the whole maze than for the whole groups.

TABLE VII

		PW VIII		PW IX	
Group of rats		Part	Whole	Part	Whole
Trials	Parts	89.6 / 4		121.8 / 4	
	Whole	7.6		23.0	
	Both	30.0	25.2	53.45	20
Time	P	35′ 23.64″		48′ 49.32″	
	W	12′ 36.10″		37′ 8.54″	
	B	47′ 59.74″	38′ 40.5″	85′ 57.86″	31′ 52.9″
Number of errors:					
Retracing in true path	P	7.2		6.0	
	W	1.6		4.8	
	B	8.8	7.0	10.8	9.4
Blind forward	P	46.6		43.0	
	W	9.6		20.8	
	B	56.2	40.8	63.8	44.8
Blind backward	P	1.4		3.2	
	W	1.6		1.6	
	B	3.0	3.6	4.8	6.6
All kinds	P	55.2		52.2	
	W	12.8		27.2	
	B	68.0	51.4	79.4	60.8
Number of units of excess distance:					
In true path	P	275.2		226.4	
	W	102.8		220.8	
	B	378.0	288.8	447.2	493.6
In false path	P	968.8		845.6	
	W	216.0		394.0	
	B	1184.8	870.8	1239.6	974.4
Total	P	1244.0		1072.0	
	W	318.8		614.8	
	B	1562.8	1159.6	1686.8	1468.0
Number of units of total distance traveled	P	10293.6		13099.75	
	W	3389.2		9699.8	
	B	13682.8	11340.4	22799.55	9368.0
Rats used		54, 64, 73, 75, 76	60, 66, 68, 70, 74	60, 66, 68, 70, 74	54, 64, 73, 75, 76

Table VII gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true and in the false pathway, and number of units of total distance travelled. Trials were computed, errors classified and counted and units of total distance determined as in the part methods previously used. Examination of these data shows that in every particular, excepting in errors of the blind-backward type in both mazes and units of excess distance in the true path in Maze PW IX, the whole groups were superior to the part groups in learning the mazes. With some exceptions this was true for individuals as well as for groups. In the results obtained from Rat 73, the part procedure proved to be equal or superior to the whole procedure in all items. For Rat 76 the part procedure proved to be superior in six of the ten items compared, but the whole procedure excelled in respect to time, blinds taken while running in a forward direction, excess distance in the false pathway, and total distance travelled. Rat 54 retraced more, Rats 60, 64, and 70 took more excess distance in the true pathway, Rat 68 made more errors of the blind-backward type, and Rat 75 retraced more and made more errors of the blind-backward type in learning by the whole method than in learning by the progressive part method. Nearly all of these exceptions are due to the peculiar behavior of the rats of the whole group at one particular point in Maze PW IX. For some reason which the writer has been unable to determine certainly, in their early runs most of the animals of that group, on reaching the fourth alley of the seventh pathway, turned back and retraced a large part of the section already run. In some runs they repeated this behavior several times before finally proceeding into the next alley and completing the run. This, of course, resulted in an accumulation of excess distance and of errors of the retracing and blind-backward types, and detracted from the superiority of the whole procedure for that maze. In spite of this peculiar reaction on the part of that group of animals, when averages were taken for all rats and the part and whole groups were compared, the whole procedure proved to be the superior one for Maze PW IX in all

excepting two items—errors of the blind-backward type and excess distance in the true path. In fact, in three items—number of trials, amount of time, and number of units of total distance—the rats of the part groups before they were set to running the maze as a whole had already reached averages greater than the averages for the rats of the whole group in learning the mazes as wholes. The averages are:

	PART GROUPS ON PARTS	WHOLE GROUPS ON WHOLES
Trials	26.425	22.6
Time	42′ 6.47″	35′ 16.7″
Errors	53.7	56.1
Excess distance	1158.0	1313.8
Total distance	11696.7	10354.2

When both mazes are taken together, the whole method was superior in all items excepting errors of the blind-backward type, and the difference in favor of the progressive part method in that item was small.

Table VIII gives the average differences in favor of the whole procedure for each of the mazes separately and for the two mazes combined both in absolute amounts and in percentages. It will be observed that by whatever criterion the two methods are compared there was an advantage for the whole method—39.1% in number of trials, 41.15% in amount of time, 23.9% in number of errors, 19.3% in number of units of excess distance, and 38.0% in number of units of total distance travelled.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure and the progressive part procedure in this study we find

1. That the whole procedure was superior, whatever be the criterion applied. In respect to number of units of total distance travelled, which is the best measure of energy spent, the advantage for the whole procedure was 38.0%.
2. That the advantage in favor of the whole procedure was greater when it was compared with the progressive part procedure than when it was compared with the pure part

and modified reversed repetitive part procedures, and less when it was compared with the reversed repetitive part procedure.

3. That in the progressive part procedure, the learning acts required before the maze was run as a whole constituted more than $\frac{2}{3}$, and completing the learning by running the maze as a whole less than $\frac{1}{3}$ of the learning activity.
4. That learning the parts and part combinations by the progressive part method did reduce the amount of energy required to finally master the maze as a whole.

TABLE VIII

	PW VIII		PW IX		PW VIII AND IX	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	4.8	16.0	33.45	62.2	19.125	39.1
Time	9′ 19.24″	19.4	54′ 4.96″	62.9	31′ 42.1″	41.15
Errors:						
Retracing in true path	1.8	20.4	1.4	13.0	1.6	16.7
Blind foward	15.4	27.4	19.0	29.7	17.2	28.55
Blind backward	−.6	−20.0	−1.8	−37.5	−1.2	−28.75
All kinds	16.6	24.4	18.6	23.4	17.6	23.9
Excess distance:						
In true path	89.2	23.6	−46.4	−10.3	21.4	6.6
In false path	314.0	26.5	265.2	21.3	289.6	23.9
Both	403.2	25.7	218.8	12.9	311.0	19.3
Total distance	2342.4	17.1	13431.5	58.9	7886.9	38.0

5. That in number of trials taken, amount of time required and units of total distance travelled, the amount of energy expended by the rats of the part groups on learning the parts and part combinations, exclusive of the combination I–II–III–IV, exceeded that expended by the rats of the whole groups on learning the maze as a whole. In respect to errors and excess distance this was not true.

E. Comparison of whole with direct repetitive part procedure

One pair of mazes and 11 rats were used to compare the relative effectiveness of the whole and the direct repetitive part proce-

dures in learning. The first maze, PW X, contained 369 units of true and 152 units of false pathway; the second, PW XI, contained 376 units of true and 154 units of false pathway. In learning the first maze the rats numbered 60, 66, 68, 70, 74 and 78 constituted the "whole" group and those numbered 54, 64, 73, 75 and 79 constituted the "part" group. In learning the second maze the groups were reversed.

For each maze the procedure was as follows: each rat of the part group ran in Part I of the maze eight times per evening until three successive correct runs had been made. Then he was again put into Part I and required to run Parts I and II together four times per evening until three successive correct runs had been made. Next he was required to run Parts I, II and III in combination three times per evening (two times each third evening) until three successive correct runs had been made. Finally he was required to run the whole maze, that is, Parts I, II, III and IV in combination. Each of the rats of the whole group ran the entire maze two times per evening until all of the rats of the part group were ready to run the maze as a whole, when the number of runs was increased for all rats that had not yet completed the learning. Seventeen evenings were spent on Maze PW X and twenty-two evenings on Maze PW XI. The general procedure employed was that described in Section II D above.

This procedure, it will be observed, is similar to that employed in the reversed repetitive part method in the respect that with each transfer to a new combination of parts the animal was confronted with a new problem which included both the review of an already learned section and the mastery of a new one. The two procedures differ, however, in the order of attack. In the reversed repetitive part method the animal ran first a new section of the maze and then one or more already learned sections. In this method the order was reversed, the animal after each transfer running from an already learned section into a new one.

The learning of Part I by the animals of the part group and of the maze as a whole by the animals of the whole group proceeded in the way described for the learning corresponding units in pre-

TABLE IX

		PW X		PW XI	
Group of rats		Part	Whole	Part	Whole
Number of trials	P	$\frac{90.6}{4}$		$\frac{92.33}{4}$	
	W	34.5		34.16	
	B	57.15	33.66	57.24	50.8
Time	P	38′ 42.76″		36′ 4.01″	
	W	53′ 52.14″		55′ 30.72″	
	B	1 hr. 32′ 34.90″	1 hr. 2′ 30.28″	1 hr. 31′ 34.73″	1 hr. 19′ 48.7″
Number of errors:					
Retracing in true path	P	12.0		7.3	
	W	9.2		6.7	
	B	21.2	15.0	14.0	7.4
Blind forward	P	35.6		35.2	
	W	39.2		36.3	
	B	74.8	53.8	71.5	83.0
Blind backward	P	6.0		4.2	
	W	2.0		2.8	
	B	8.0	9.8	7.0	3.2
All kinds	P	53.6		46.7	
	W	50.4		45.8	
	B	104.0	78.6	92.5	93.6

Number of units of excess distance:					
In true path	P	495.2		446.0	
	W	377.6		432.7	
	B	872.8	1028.0	878.7	234.4
In false path	P	878.8		836.0	
	W	716.0		826.7	
	B	1594.8	1110.3	1662.7	2378.8
Total	P	1374.0		1282.0	
	W	1093.6		1259.4	
	B	2467.6	2138.3	2541.4	2613.2
Number of units of total distance traveled	P	9731.8		9961.02	
	W	13824.1		14103.56	
	B	23555.9	14558.8	24064.58	21714.0
Rats used		54, 64, 73, 75, 79	60, 66, 68, 70, 74, 78	60, 66, 68, 70, 74, 78,	54, 64, 73, 75, 79

ceding problems. When the rats of the part group had completed the learning of Part I and were put upon Parts I and II in combination, in the first few runs they stopped at the point of transition between the two sections, pushed and pawed at the panel blocking the path which had previously led into the food box, and sometimes retraced into the latter paths of Part I, though more often they proceeded into Part II after a brief hesitation. These hesitations, however, were quickly dropped. With the addition of Part III and Part IV in turn there was the same tendency to hesitate at transition points and also the same tendency after only a little practice to proceed smoothly from one section to the next. The behavior of the animals in running the already learned portions was in each case the same as their behavior in running any maze with which they were familiar, and the newly added sections were learned just as any other maze or part of a maze. There was little disturbance in the running of the already learned portions from having added the new increment from time to time.

Table IX gives for each group of rats on each of the two mazes the averages in number of trials, amount of time, number of errors of each type, number of units of excess distance taken in the true and in the false pathway, and number of units of total distance travelled. Examination of these data shows that with exceptions in a few items the whole groups were superior to the parts groups in learning the mazes. In PW X the number of errors of the blind-backward type and the number of units of excess distance in the true path were greater for the whole group; in PW XI the number of errors of the blind-forward type, the total number of errors, the number of units of excess distance in the false pathway, and the total number of units of excess distance were greater for the whole group than for the part group. When, however, the averages of results from both mazes are taken, the part group had an advantage in only one item, the number of units of excess distance taken in the false pathway, and this advantage was small. This superiority in learning by the whole method was in general true for the individual animals but with some interesting exceptions. Rats Number 54 and 73, both of

which learned Maze PW X by the part method, showed differences in favor of the part procedure in respect to number of trials, amount of time, number of errors of the blind-forward type, number of units of excess distance in the false pathway, and number of units of total distance travelled. Other differences in favor of the part method were

Rat 60—number of errors of the blind-forward type and of the blind-backward type, and excess distance in the false pathway.
Rat 64—excess distance in the false pathway.
Rat 68—number of errors of each type and number of units of excess distance in both the false and the true pathways.
Rat 78—number of errors of the retracing-true and blind-backward types and excess distance in the true pathway.
Rat 79—number of trials and number of errors of the blind-forward type.

When we apply the criterion which is the best measure of energy required for learning, namely, the number of units of total distance travelled, the whole procedure proved to be the superior one for all rats excepting Number 54 and Number 73. In spite of these exceptions for animals taken separately, when averages are computed for both mazes and for all rats the advantage was in favor of the whole method. Table X gives the average differences in favor of the whole method for each of the mazes separately and for the two mazes taken together, both in absolute amounts and in percentages. It will be observed that for some items the part procedure had the advantage—in Maze PW X for errors of the blind-backward type and units of excess distance in the true path; in Maze PW XI for errors of the blind-backward type, total errors and total units of excess distance; but in the average of the two mazes taken together only for units of excess distance in the false pathway. Expressed in terms of the criteria employed, the superiority of the whole procedure over the direct repetitive part procedure was 26.1% in number of trials, 22.7% in amount of time, 11.6% in number of errors, 5.25% in units of excess distance, and 23.9% in units of total distance travelled. These percentages were in general less than the percentages of advantage for the whole procedure when compared with other

part procedures with the exception of the modified reversed repetitive part procedure in which only partial learning of each part combination was required before the next increment was added. In other words, the direct repetitive part procedure compared more favorably with the whole procedure than any other included in this study excepting the modified reversed repetitive part procedure.

It is again of interest to note the relative amount of learning effort given by the part groups to the learning of the parts in combination through Parts I, II and III and to the learning of the whole by the addition of Part IV. The results obtained from the two mazes show that for each of the part combinations taken separately, for all of them taken together, and for the mastery of the whole after Part IV was added, the percentages were

TABLE X

	PW X		PW XI		PW X and XI	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
Trials	23.49	41.1	6.44	11.2	14.97	26.1
Time	30′ 4.6″	32.5	11′ 46.0″	12.8	20′ 55.3″	22.7
Errors:						
Retracing in true path	6.2	29.2	6.6	47.1	6.4	38.1
Blind forward	21.0	28.0	−11.5	−16.0	4.75	6.0
Blind backward	−1.8	−22.5	3.8	54.3	1.0	15.9
All kinds	25.4	24.4	−1.1	−1.2	12.15	11.6
Excess distance:						
In true path	−155.2	−17.8	644.3	74.4	244.5	28.3
In false path	484.5	30.4	−716.1	−43.0	−115.8	−6.3
Both	329.3	13.3	−71.8	−2.8	128.75	5.25
Total distance	8997.7	38.1	2350.6	9.7	5673.8	23.9

	I	I–II	I–II–III	Parts	Whole
Trials	3.0%	14.0%	23.0%	40.0%	60.0%
Time	3.7	15.0	21.8	40.5	59.5
Errors	5.8	22.5	22.7	51.0	49.0
Excess distance	5.3	25.4	22.3	53.0	47.0
Total distance	3.9	15.9	21.5	41.3	58.7

With this method, up to the point where the part combinations (exclusive of the final combination making the whole) had been mastered, the proportion of energy expended by the rats of the part groups was a little less than $\frac{1}{2}$ of the total amount of energy required for complete learning.

Compared with the reversed repetitive part procedure the direct repetitive part procedure showed certain very marked advantages. In learning by the latter method the hesitations and retracing errors at points of transitions between parts immediately after a new increment had been added were less serious and were more quickly dropped. As was to be expected, the addition of the new increment had no effect on the running of the part already learned and at no time did an animal behave in an already learned section as if he were not familiar with it. Not nearly so large a proportion of the total energy expended was required to master the first three of the four parts learned and in no item was more energy used by the rats of the part groups in mastering these first three parts than was used by the rats of the whole groups in learning the maze as a whole. As before, that there was some learning retained from having learned the first three sections by this direct cumulative method is indicated by the fact that the amount in trials, time, errors, excess distance and total distance was in general less for the rats of the part groups after they were set to running the maze as a whole than for the rats of the whole groups.

Summarizing the results obtained by experimental testing of the relative effectiveness of the whole procedure in this study, we find

1. That the whole procedure was superior, whatever the criterion applied. In respect to number of units of total distance travelled the advantage for the whole procedure was 23.9%.
2. That the advantage for the whole procedure was somewhat greater when the whole procedure was compared with the direct repetitive part procedure than when it was compared with the modified reversed repetitive part proce-

dure; but less when the whole procedure was compared with the direct repetitive part procedure than when it was compared with the reversed repetitive part procedure, the progressive part procedure, or the pure part procedure.

3. That in the direct repetitive part procedure, learning three of the four parts of the maze constituted approximately $\frac{1}{2}$ and completing the learning by the addition of the fourth part approximately $\frac{1}{2}$ of the learning activity.
4. That, when all criteria are taken together, learning Parts I–II–III in combination by the direct repetitive part method did reduce somewhat the amount of energy required to master the whole after Part V had been added.
5. That the direct repetitive part method compared more favorably with the whole method in effectiveness in learning than any other method tested excepting the modified reversed repetitive part method.

IV. CONCLUSION

From the results obtained in the experiments described in the earlier sections of this paper we feel justified in concluding that, for rats learning maze patterns, the whole method is superior to either the pure part method, the reversed repetitive part method, the modified reversed repetitive part method, the progressive part method, or the direct repetitive part method.

In every test made the whole procedure proved to be superior in respect to all the criteria employed. In respect to number of units of total distance travelled, which is the truest measure of energy expended, the advantage of the whole method amounted to 26.7% in comparison with the pure part method, 44.5% in comparison with the reversed repetitive part method, 13.6% in comparison with the modified reversed repetitive part method, 38.0% in comparison with the progressive part method, and 23.9% in comparison with the direct repetitive part method. The advantage of the whole method in respect to each of the criteria when compared with the part methods was

	MOD. REV. REP. PART	DIR. REP. PART	PURE PART	PROG. PART	REV. REP. PART
Trials	12.05%	26.1%	25.8%	39.1%	44.1%
Time	14.50	22.7	18.0	41.15	41.5
Errors	19.10	11.6	27.8	23.9	43.1
Excess distance	19.21	5.2	31.1	19.3	45.0
Total distance	13.6	23.9	26.7	38.0	44.5

Of the methods of learning tested, the order of effectiveness from greatest to least was whole, modified reversed repetitive part, direct repetitive part, pure part, progressive part and reversed repetitive part. Whenever the total pattern was broken into parts and then combined again into the whole, the process of learning required the expenditure of more total energy than when the pattern was kept unbroken throughout the learning period. It is evident that in these tests learning the parts and part combinations first did not interfere with learning the mazes as wholes finally, for the rats of the part groups were able, after the parts had been mastered, to master the whole with less effort than the rats of the whole groups. In other words, there was an actual saving in the amount of energy required to master each maze as a whole by having first practiced the parts separately. The results on the reversed repetitive part and the modified reversed repetitive part methods indicate that the amount of this saving was somewhat greater when the parts were really mastered than when they were given only a limited amount of practice. The table below gives the percentages of saving for each of these two methods.

	REV. REP. PART METHOD	MOD. REV. REP. PART METHOD
Trials	44.1%	34.5%
Time	45.8	35.2
Errors	44.6	41.1
Excess distance	31.8	42.0
Total distance	42.0	35.3

Notwithstanding the fact that energy was saved in learning the whole by having first learned the parts and that more was saved

when the parts were mastered than when they were only partially learned, there was actual waste of energy in learning by the part methods in comparison with the whole method when total energy required is considered. The saving on the final learning of the whole was much less than the energy expended on the parts. All this was true in spite of the fact that whenever in the procedure an advantage had to be given to one group or to the other, it was given to the part group. The part group had an advantage in the counting of time. The time spent in the early alleys of each part and part combination was counted out for them while only the time spent in the alleys of the first part was counted out for the rats of the whole groups. Another possible item in their favor was the greater number of runs given them per evening. If, as seems probable, the amount of energy required to make the standard score is in any measure a function of the massing of effort, the rats of the part groups had the advantage in this respect. As soon as all of them were ready for the whole the number of runs per evening was increased, so that they probably reached the score relatively more quickly than they would have done if their practice on the whole maze had been as distributed as in the case of the rats of the whole groups. This means that the whole groups were required to acquire a pattern that, after the lapse of considerable time, would probably be better retained than in the case of the part groups. Despite these facts, the whole method proved to be the superior one in comparison with all part methods tested for every maze and for every rat excepting one rat on one pair of mazes (Rat 73 on Mazes PW VIII and PW IX).

This superiority of the whole procedure was demonstrated again when the data were tabulated and computed in quite different ways. Comparing the average total distance travelled by the rats of the part groups with the average total distance travelled by those of the whole groups in learning each of the mazes, the results shown in Table XI were obtained. Again the relative effectiveness of a run on four parts as compared with a run on the whole was determined by taking the amount saved

TABLE XI

MAZES	RATS OF WHOLE GROUPS	RATS OF PART GROUPS			PER CENT AVERAGE TOTAL DISTANCE RUN BY A RAT OF THE PART GROUP IS OF THAT RUN BY A RAT OF THE WHOLE GROUP $\frac{x}{y}$
	Average total distance y	Average total distance on parts	Average total distance on whole	Average total distance x	
Last three correct runs on parts included					
PW VI and VII	10419.20	5120.90	6738.95	11859.85	113.8%
PW X and XI	18136.40	9846.41	13963.83	23810.24	131.2%
PW II and III	9099.10	4560.44	8032.52	12592.96	138.3%
PW VIII and IX	10354.20	11696.68	6544.50	18241.18	176.1%
PW IV and V	12029.70	14525.95	6968.50	21494.45	178.6%
Last three correct runs on parts excluded					
PW X and XI	18136.40	8270.16	13963.83	22233.99	122.4%
PW II and III	9099.10	3454.94	8032.52	11487.46	126.2%
PW VIII and IX	10354.20	9000.03	6544.50	15544.53	150.1%
PW IV and V	12029.70	12686.65	6968.50	19655.15	163.3%

TABLE XII

	WHOLE METHOD	PW VI AND VII	PW X AND XI	PW II AND III	PW VIII AND IX	PW IV AND V
		Modified reversed repetitive part method	Direct repetitive part method	Pure part method	Progressive part method	Reversed repetitive part method
Last three correct runs on parts included						
Trials	100%	75%	34%	19%	27%	37%
Time	100	68	44	46	24	39
Errors	100	63	75	50	67	37
Excess distance	100	58	90	43	73	25
Total distance	100	71	42	24	32	34
Last three correct runs on parts excluded						
Trials	100	75	50	30	42	39
Time	100	68	51	67	33	45
Errors	100	63	75	50	67	37
Excess distance	100	58	90	43	73	25
Total distance	100	71	49	33	41	39

for the rats of the part groups in learning each maze as a whole due to first having mastered the parts, and dividing that amount by the effort required to learn the parts. This fraction was expressed as per cent. The results obtained are given in Table XII.

It is clear that whatever criterion be used, whether or not the last three correct runs required as evidence of mastery of each part or part combination be included, whether the comparison be made in terms of per cent of advantage for the whole procedure or in terms of per cent of relative effectiveness of a run on four parts as compared with a run on the whole, there proved to be a decided advantage in favor of the whole procedure when compared with any of the part procedures employed in this study.

In all tests there were some items for some rats in which the part procedure seemed to have the advantage. These were most numerous in the modified reversed repetitive part method which most closely approached the whole in degree of effectiveness, and least numerous in the reversed repetitive part method which was farthest removed from the whole in degree of effectiveness. But when all rats and both mazes in each test are taken together, however the data are computed, there was unmistakable superiority in learning by the whole method and we are forced to the conclusion that for this type of learning the whole procedure is better than any of the part procedures compared with it.

A second conclusion derived from the results obtained in these experiments is that with trained animals there is no evidence of progressively increasing facility in mastering maze patterns of comparable difficulty. When all of the other variables have been eliminated by means of thorough training of animals and of control of objective conditions, and when the problem is confined to that of learning the specific maze pattern involved, the amount of energy required for learning depends on the nature of the problem itself and on the relatively constant individual differences among the animals, not upon the amount of practice they have been given previously. In the two methods in which each part was learned separately before being attacked in combination with

other parts, the order of difficulty of learning did not show progressive decrease. In Mazes PW II and PW III, learned by the pure part procedure, the order was II, IV, I, III; in Mazes PW VIII and PW IX learned by the progressive part procedure, it was I, IV, II, III.

A third conclusion reached is that the learning of one maze or part of a maze, when it is unique in character, does not affect either positively or negatively the learning of later mazes. This was demonstrated by the fact that there were on the part of the rats no consistently increasing readiness or reluctance to attack new problems, no significant differences in energy required to learn successive mazes, and no changes in general behavior from one problem to another. In all tests, parts of mazes or mazes that were learned as wholes were mastered in very much the same way.

A fourth conclusion is that the problem of the relative value of distributed and massed repetitions in immediate recall is in pressing need of further investigation. There is some evidence in the test of the reversed repetitive part method that the decrease in number of runs per evening as the part combinations became larger resulted in disproportionate increase in the amount of energy required for reaching the score. It has not been the purpose of this study to investigate the problem of distribution of repetitions, hence no conclusion can be derived, but the results suggest that massing of effort may be a factor influencing efficiency in learning of this type.

The results obtained and the conclusions reached are in harmony with the findings of all earlier investigators and of many of the recent investigators using rote and meaningful material and human subjects. They are in disagreement with the findings of those who have used motor learning material and with the findings of Pechstein (18) who used animal subjects. Pechstein ranked the learning methods in the order of merit as follows: progressive part, reversed repetitive part, direct repetitive part, pure part, and whole (returns allowed); the writer found the order to be whole, direct repetitive part, pure part, progressive part, and reversed repetitive part, with little advantage for the

progressive part over the reversed repetitive part procedure. The order obtained by Pechstein seems to the writer to be in general what should be expected under the conditions of his experiment. Beginning with rats lacking experience in maze running, those part methods in which the learning problem gradually became more complex would of necessity be more effective in building up the food association, overcoming unfavorable emotional reactions, establishing general maze habits, and preparing the animal for the increasing length of path due to the small increments added from time to time. Animals already trained to run all kinds of maze lengths would have those items mastered in advance. The problem for them would include only the learning of the maze pattern involved and not, in addition, the items named above. Of the two methods found by Pechstein to be best, the progressive part and the reversed repetitive part, one would expect the former to be superior to the latter, the forward learning or the passing from the familiar into the new to be better than the reverse. As stated by Cameron (4, 29), "the tendency in psychology to-day is toward a recognition of the relationship existing between the total form of the stimulating situation and the adequacy of the response." In going from the familiar into the strange the animal began with the pattern which had already been built up, that is, with the total form unimpaired. In going from the strange into the familiar, the pattern already acquired was broken up and the learner had to rebuild his pattern anew. When the problem had been reduced to the single task of learning a specific pattern and the results were not obscured by other factors, the difference was clear. In the tests of the reversed repetitive part and the progressive part methods described in this paper, where the variable factors of emotional tone, etc. had been eliminated and the only learning problem present was that of the specific maze design, the animals found it more difficult to run from the new into the already-learned part without error in the latter than to combine two previously mastered sections and run them together without error in either. In the former they were obliged to reconstruct the total form anew; in the latter the patterns learned seemed to become functional parts of the new

whole. In learning by the direct repetitive part method, the established pattern was not necessarily disorganized with the addition of each new increment, as in the reversed repetitive part method. On the other hand, the excessive amount of retracing points to probable fear of the new and tendency to retrace, which in the progressive part method had been obviated by having each part learned separately before it became a part of a larger whole. Which of these two factors—disorganization of established pattern or emotional disturbance—is the more important is not known.

When we consider the two methods which Pechstein found least effective, the pure part and the whole, we find again that his results are what one would expect with untrained animals. In the pure part method the animal, during the learning of the earlier parts, seems to have overcome the unfavorable emotional tone and to have become accustomed to the maze situation as before. But at the same time he apparently formed the habit of making short runs and this habit tended to hamper him in making the adaptation to the longer path when he was suddenly transferred from running the last quarter to running the maze as a whole. In the whole method the inexperienced animal was set to running the longer path with even less preparation for it than was provided in the pure part procedure. Much retracing resulted. This obviously was due, not only to the fact that the animal was transferred abruptly from no run at all to a long run, but also to the several unmeasurable variable factors present because untrained animals were used. The presence of these factors makes it impossible to compare the whole procedure as employed by Pechstein and as employed by the writer.

From such considerations we may suggest that the advantage for the whole over the part procedures as used in the experiments described in this paper lies in large part in the following facts: the unity of total pattern was maintained throughout the entire learning period; there was but one learning act instead of four, five or seven, as in the part procedures; and learning was always in the forward direction, the direction in which it had to function, and never reversed. The second and third points are perhaps only special cases of the first. In the modified reversed repetitive

part procedure the parts were not thoroughly learned, less energy was expended at small return, and this procedure most nearly approached the whole in effectiveness. In learning by the direct repetitive part method there was advantage in that learning was in the forward direction and cumulative and the distances involved became gradually longer, but there was also some disadvantage due to the fact that the process was divided into four separate learning acts. In the progressive part and reversed repetitive part methods, which differed little in effectiveness, the former had the disadvantage of requiring a larger number of separate learning acts, the latter of requiring learning in the reverse direction from that in which it must ultimately function. The pure part method had the advantage of requiring fewer learning acts than the progressive part method but more than the direct repetitive part method. In comparison with the reversed repetitive part method it had the advantage of requiring learning in the forward direction, the direction in which the learning must ultimately function. Hence the order—whole, modified reversed repetitive part, direct repetitive part, pure part, progressive part, and reversed repetitive part—seems to be the logical order of effectiveness for methods used with trained animals in maze learning.

The results of this experiment are in disagreement with those obtained by Pechstein again in respect to compatibility of parts learned as parts with other parts or with the whole. Pechstein found that "they may function perfectly as parts, in any successive combination of parts, or in the entire motor series" (18). It has already been pointed out that such was not the case in the experiments described. Each part when combined with another or when combined with all the others to form the whole, did not at once function perfectly, but in its new relationship required considerable practice for mastery. It seems probable that the similarities among parts in Pechstein's maze—the general principle governing options at junctions, the similarities in length, arrangement and character of true paths in the different parts and of the character and distances of culs de sac—account for this difference in results. In mazes where each part was unique,

where no specific details of patterns could be carried over to form part of another pattern, the results show that there was no such immediately functioning compatibility among parts.

It is possible, too, that individual differences among the animals may have affected the results obtained by Pechstein. Different rats were used in the whole groups and in the part groups and new groups were used for each of the methods tested. In the present experiment the influence of individual differences was obviated by having each rat serve in both groups for each of the comparisons made between the whole and a part procedure. It seems apparent to those who work with rats that the individual differences are sufficiently great that they cannot be regarded as negligible, but further experimentation is necessary before we can measure exactly the degree of influence of that factor.

Summarizing the results of this experiment we find:

1. The whole method proved to be superior to either the pure part, progressive part, reversed repetitive part, modified reversed repetitive part, or direct repetitive part methods for rats in learning maze patterns.

2. Practice on parts and on part combinations before running the whole contributed to learning, but did not save enough to compensate for the extra energy required.

3. Some important factors in causing waste in part learning were

a. Breaking up the unity of the total pattern.

b. Increasing the number of separate learning acts.

c. Learning in a direction opposite to that in which the learning must ultimately function.

4. Compatibility of parts learned as parts when required to function with other parts or with the whole was not immediate, but required practice of the part in its new relationship.

5. Trained learners did not acquire increasing facility in learning problems of similar type and of comparable difficulty. They had attained a considerable uniformity of performance.

6. The mastery of one part did not affect either positively or negatively the mastery of others when the problems were unique in character.

7. The influence of distribution of repetitions on amount of energy required for learning for immediate recall is in need of further experimental study.

8. Individual differences among learners is a probable factor in learning efficiency regardless of method employed.

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